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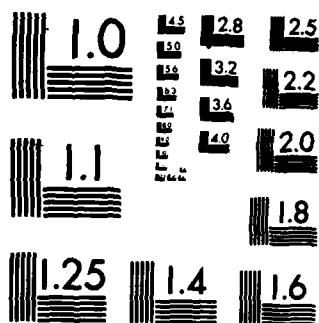
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VOL. 9, NO. 3

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# SCIENTIFIC BULLETIN



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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This is a quarterly publication presenting articles covering recent developments in Far Eastern (particularly Japanese) scientific research. It is hoped that these reports (which do not constitute part of the scientific literature) will prove to be of value to scientists by providing items of interest well in advance of the usual scientific publications. The articles are written primarily by members of the staff of ONR Far East and		

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19. Key Words (continued)

Narrow gap welding	GaAs
Gas metal arc welding	III-V compound semiconductors
Submerged arc welding	Integrated circuits
Gas tungsten arc welding	Bulk crystals
Japan	Japan
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Ocean bottom	CSIRO
Ocean characteristics	Australia
Takutei Kenkyu	Parkes Radio Telegraph
Mombusho	Culgoora Solar Observatory
Seawater transport	Radio astronomy
Membrane research	Japanese psychology
Ions	Japanese Psychological Assn
Selective permeability	Experimental psychology
Transmitter release	Personality
Enhancer	Developmental psychology
Inhibitor	
Channel kinetics	

20. Abstract (continued)

and the Air Force Office of Scientific Research with certain reports also being contributed by visiting stateside scientists. Occasionally, a regional scientist will be invited to submit an article covering his own work, considered to be of special interest.

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Cover: Three elements in the Japanese garden that are in agreement with nature and pleasing to man: stone, plants, and water. All three are combined in the tea garden of Tsunekichi Oka of Isshiki, Hayama, Japan. The photograph, taken on a summer day in Hayama, is contributed by Erin Moore.

# AUTOMATIC RECOGNITION OF HANDPRINTED CHINESE-JAPANESE KANJI: THE LAST FRONTIER OF CHARACTER RECOGNITION?

Nicholas A. Bond, Jr.

To the naive Western observer, written Japanese looks mysterious indeed. Though occasional English alphamerics such as numerals, names, and mathematical symbols appear in Japanese text, most written material is expressed either in kana phonetic symbols or in kanji characters. After many years of standardization and simplification, the kana are relatively simple characters which require only two or three strokes to write, and they are rather easily recognized by man or machine. For example, in the fragment of text below taken from a Japanese scientific journal, the characters in the right half of the fourth line are kanas. Many of them resemble the l's, t's, and p's of Western typography. There are a total of 92 kana, and they can be learned in a few days or weeks by Western visitors to Japan.

電子ビーム直接描画の可能性は、  
1979年に、米IBM社のGrobmanら  
によって実証されている。この電子ビ  
ーム直接描画法のレイアウト・ルール  
は、1.5~1  $\mu$ m時代のそれに近い。

Kanji characters, though, are a different matter altogether. Those complex characters appearing in the middle of the top line above, and in the left side of the fourth line, are kanji, and it is evident that there are serious problems in discriminating among them. First, and worst, is the sheer complexity; there can be more than a dozen strokes in a single character with many little edges and areas. Then there is the similarity among characters; with so much information encapsulated into such a small space, similarities and hence confusions can be expected; it takes only a little blurring to destroy discrimination entirely. Then the sheer number of kanji is a problem. In Japanese schools, all pupils are expected to know about 800 kanji characters by the equivalent of the sixth grade (age 11 to 12); and about 2000 characters are used in general circulation newspapers and magazines. At the human learning level, the mastery of all these kanji is a major part of the educational process, and thousands of hours in Japanese schools are devoted to kanji drill and practice. Indeed, some observers even hypothesize that the effort required to learn kanji explains the superiority of Japanese school pupils on IQ tests. So much intensive drill and practice, it is alleged, tends to encourage the formation of certain intellectual habits (attention to detail, willingness to undertake long memorization drills, and so forth). And so, the argument goes, Japanese children tend to perform well on a variety of intellectual tasks such as those sampled on IQ tests.

However useful such educational speculations may turn out to be, there is no doubt that kanji are hard to read. Automatic machine readers for printed kanji are coming into practical use, and they work now even though there are many slightly different type fonts for printed characters. One printed character processing scheme from a Nippon Telegraph and Telephone laboratory uses a two-stage classification; the procedure is shown in Figures 1 and 2. First, an input character is normalized into a rectangular area

of 8 x 8 subareas; for each of the 64 subareas, proportions of the black part are recorded as a 64-dimensional scalar or mesh vector. Thus, the illustrative character in Figure 1a has zero scores in about a third of the subareas.

When all the simple black-white scalars have been entered, the scanner then gets a peripheral measure which looks at the area between the edge and the first change (from white to black) toward the opposite character frame (Figure 2a). A similar area score is recorded for the second area of transition from white to black (Figure 2b). For each thin line there are two measures, and when these scores are taken in all four orthogonal directions, a 64-dimension peripheral vector is recorded. The NTT system uses the best of the mesh vectors for rough screening, then applies a Bayesian rule to the peripheral information for a final decision. Very high recognition rates for printed characters are now observed, with errors of much less than one percent, even for different type fonts. Computation and storage requirements are now, or soon should be, in the manageable range, again for printed characters. Real time processing is promised shortly.

Handprinted kanji characters can differ widely, of course, with respect to individual variations in handwriting style, stroke width, type of writing implements, angle of attack, and so forth. One can also expect individual differences in the care exercised in scripting the material. So the recognition problem is obviously much more difficult, and it is no wonder that some workers have dubbed it the last frontier in character recognition. Remarkably, high recognition rates now can be achieved with handprinted kanji input. The methods used are interesting in themselves and perhaps the successes achieved will be relevant to other pattern recognition challenges, such as those associated with the Fifth Generation Computer Project. Intensive work is underway at several places, and there is very real competition among laboratories right now. In the few weeks between the time this report is written and the time it is received by readers, new progress may be reported. All we attempt to do here is to give the flavor of a few recent approaches and results.

- Hong Kong University

All the systems that are nearing practicality use multipass methods. At Hong Kong University, H.K. Tsui has concentrated on the second or fine processing stage, because he believes that almost any current first pass classification scheme will reduce the number of candidates from 2000 down to a reasonable number, say 50 to 100 patterns. On Tsui's scheme, once you are inside this smaller set, you perform an intensive stroke analysis. A stored battery of 25 fundamental strokes is a key resource. These 25 strokes are supposed to reflect many of the natural stroke patterns used by native readers and writers. The set of strokes is shown in Figure 3. After an (unknown) input pattern is received, scaled, and centered, stroke-scanner operators start to look for strokes. Eventually the observed strokes in the input are matched with a reference stroke table for each of the 50-100 possibilities.

Exponential indexes for the similarity of any given input to all the stored possibles are then computed. As an illustration of these indexes, stroke direction differences between an input and a reference would be scored as:

$$P_d = e^{-\frac{(d_i - d_r)^2}{C_1}}$$

where  $d$  are the directions and  $C_1$  is a fitted scaling constant. Separate indexes are calculated for stroke length and for stroke head location. Tsui also uses a dark point

ratio measure which reflects the proportion of dark points in the unknown input pattern. Finally, all the indexes are assembled and a grand similarity product is obtained. The name of the stored character with the highest product is then designated as the (previously unknown) input.

Tsui's rather unusual validation scheme was to take 1100 of the most frequently used Chinese characters as the population of interest (these characters are quite similar to Japanese kanji; in fact, kanji are derived from Chinese typography). Then, two persons printed 40 of these characters each into the computer. A third person also did the same 40 characters, and a reference table for these 40 was made and stored in the computer. Some thousands of computed matchings yielded practically no errors. This impressive outcome was, of course, incomplete; a working classification system was not put together and evaluated for its total performance on realistic material. What Tsui showed clearly, though, was that an ingenious second stage processing scheme can work very well indeed on character sets that have been previously delimited.

- Toshiba Corporation

At the Toshiba Information Systems Laboratory (Kawasaki, Japan), a two-stage scheme is also employed, with the first screening designed to reduce the number of possibles down to 100 or less. Twelve parameters are taken from each input figure; these parameters express the number of lines, the peripheral background area, and the line lengths in each (box normalized) input. Figure 4 illustrates the scoring process for the kanji character "den." The figure space is segregated into four half-areas: upper, lower, left, and right halves. Line numbers for the left half is derived from a weighted summation of adjacent dark cells in the figure matrix. Thus, the algebraic formula for line number index  $L_L$  is

$$L_L = \frac{\sum l_x + \sum l_y + \sum l_s / \sqrt{2} + 2 \sum l_t}{H/2 + V},$$

where the values are as shown in Figure 4. Peripheral background is taken as a summation of first white run length ( $P_R$  in Figure 4) count, whereas center line length takes the absolute difference between white run lengths for adjacent lines ( $C_R$  in Figure 4).

The 12 input parameters of an (unknown) character are compared with stored sets of means and variances of previously recorded samples; an input qualifies if the absolute difference between the input parameters and the stored ones is less than some constant  $C$  times the standard deviation in the (stored) data. This first stage procedure is quite effective at reducing the candidates as tests on thousands of inputs have shown.

Once an input has been confined to a reduced set of 50 to 150 designations, rather intensive further processing is still required. This is because characters which have about the same gray level look are really different. An illustration is given in Figure 5. A really adequate classifier must be able to handle such structural differences. The Toshiba investigators use a blurring function for processing gray level information around a point; purportedly, noise effects such as breaks are reduced thereby. There are also innovations in the similarity calculations employed; instead of relying entirely on gray level vectors, edge and segment features are extracted by Hermitian polynomials. Considerable local pattern variation is allowable via these techniques. Thus the system

can tolerate, and in later versions might even learn how to tolerate, moderate deviations in human input patterns. The trick, of course, is to obscure the permissible deviations and still retain enough information to classify correctly.

The final or postprocessing part of the Toshiba scheme uses linguistic information, such as the change from kanji to kana notation. There is also a dictionary look up function; most high-frequency words are written by two kanji, and so confidence in an unknown character assignment improves if a straightforward two-character dictionary match can be formed. In fact, Toshiba studies have shown that the postprocessing segment corrected about half of the confusion errors which got through all the earlier processing.

Toshiba's success rate is about 90% for realistic inputs (more than 1000 candidates in the reference set). It works fast, too; the company already has a reader that can take handprinted input characters at a rate of 50 or so per second (previous Toshiba research for recognition of printed input had indicated the required rates).

- Nippon Telegraph and Telephone Public Corporation (NTT)

NTT researchers in kanji recognition (N. Hagita, S. Naito, I. Masuda, and others) have been working at the Musashino Electrical Communication Laboratory (Musashino-shi, Tokyo). Their approach also adopts a two-stage method, with a candidate selection screening being followed by a final recognition process. For some time now, the Musashino team has believed that a pattern matching scheme is superior to stroke analysis. A major reason is that the computational and dictionary requirements are perceived to be more practical for classification by pattern matching.

As it starts work on an unknown written character, the NTT scanner process looks from the outside, and records the first, second, and third intersected edges obtained from each of eight scanning directions. This intersection record can, of course, be carried to any desired depth. As Figure 6 shows, a great majority of the edges can be picked up by the time that the third periphery depth has been achieved.

From the many possible feature schemes which have been proposed, the NTT project has apparently settled upon a few feature-scoring ideas, and three of them are touched upon here (the set of score procedures changes slightly all the time as the NTT staff performs more experiments and practical trials). The Global Stroke Structure (G-DGD) is extracted as shown in Figure 7. Thirty-two basic white-black distributions result: the scanning areas are themselves broken down into 16 equal segments. Averaging along the scanning axes is then applied, as this supposedly reduces minor stroke positioning errors made by the human writer. The basic G-DGD data are then in the form of a 512-dimensional vector (32 x 16) for each unknown input.

To estimate local connectivity, complexity, and stroke direction in another way, an unknown character is broken up into an 8 x 8 square matrix of 64 local areas. Then as seen in Figure 8, contributivity is determined for four axes oriented 45° apart. In the fragment displayed, there is very little verticality but considerable horizontality of figure in the local area. The resulting 256-dimensional vector, it is hoped, would be relatively unaffected by local positioning variances or errors caused by the human writers. Also, minor local breaks should often be blurred, and hence ignored, by the averaging procedures employed.



A third major feature detector program called Peripheral Stroke Structure or P-DC, simultaneously measures the stroke complexity, direction, and relative location. Again an eight-direction outside-to-inside plan is followed; each axis is divided into 16 little sections and averaging is done over the sections as the scan moves over the figure. Figure 9 gives a glimpse of some of the resulting parameters taken from the third section scan of a character. The top four bar graphs are taken to periphery depth of one; the next four reflect a depth of two, and the bottom four were recorded by looking at the three-depth level. In this particular case, the bar graph parameters at the three level are nearly zero indicating that most of the edge information in the character is defined by peripheral depths one and two, and so the figure has a moderately low complexity. (As an incidental observation, displays such as those shown in Figure 9 are remarkably hard for humans to interpret; among the factors making for difficulty are human preferences for naturalistic or pictorial representations. Human factors people will remember that the old B-scan, and even some of the recent tactical displays used by radar intercept officers in Navy aircraft, were similarly unnatural, and required long training.)

NTT validation studies of their automatic system have been among the most thorough in Japan. Table 1 shows some of the data sets which have been run on the experimental setup at Musashino. Data set three is the Electrotechnical Laboratory compilation and has been employed in several investigations around Japan. According to NTT investigators, data set two probably had the poorest quality of input material.

For all these data sets, native Japanese subjects entered carefully written characters, using the standard kaisho style of writing. The square enclosure of a written input character, and automated placement by center of gravity, were accomplished according to a simple normalizing procedure which NTT has evolved over the years. For overall evaluation, system performance can be tabulated by the accuracies achieved in the first processing stage (where the character is delimited down to a few dozen candidates), and in the final stage (where an input character is given a specific kanji label).

Candidate selection (first screening) results were extremely good with more than 99% of inputs in data sets one and two being assigned to the right "bin" of possibilities. The recognition hit rate was also better than 90% for all three data sets. Scores G-DCD and P-DC were among the more useful ones, though NTT is still evaluating various combinations of scores and is also looking at various learning and discriminant functions for the character reading task. The overall results are clear enough; you can get above 90% accuracy right now, under laboratory conditions. NTT has built an experimental hardware setup which incorporates some of the NTT technology. The system is up and operating and is often demonstrated to visitors. When you write a kanji character in a square, the system reads it and within a few seconds a perfect example of the character appears in the space where your (imperfect) input was written; the automatically read input also goes to main storage. Corrections presumably can be made at this stage by the person doing the writing either by manual writing re-entry or by punching a special large kanji keyboard which is available on the machine for that purpose. Incidentally, it would appear that the machine might become something of a training device, as a person using it should quickly learn to shape his characters so as to keep the machine from making mistakes on his written input.

#### - Evaluation

As we have just noted, the main thing is that automatic recognition of handprinted kanji can be done right now, under laboratory conditions but with realistic data sets.

There will certainly be intense efforts to get the techniques into practical machines and we probably will see such machines before 1990.

It is tempting to speculate about the significance of these successful results for other projects now underway in Japan. The so-called Fifth Generation Computer Project has planned to produce a speech-activated system which can recognize some thousands of words, and which can also quickly accept inputs from many different speakers. Many Americans believe such a device will not be achievable for many years; the argument is that adequate models for integrating specific information about context, understanding, and individual speakers into the system do not yet exist; theoretical progress in such difficult areas is moving rather slowly.

Looking at the history of the handprinted character problem, however, one can be encouraged. A few years ago, character reading was judged to be very difficult also, and indeed with very sloppy input it still cannot be done by machines, but with a fairly high-quality input (carefully written text) and enough intensive processing, good results can now be had. In the speech recognition domain, an extrapolation of this history would suggest that for cleverly constrained and processed continuous speech inputs, practical results might well be possible within a decade or two. Thus the ultimate speech recognition problems might not be solved until well into the next century, but practical voice-actuated input devices would be available and working long before then, with rather large vocabularies and moderately constrained inputs.

As far as the writer is aware, Japanese character recognition specialists have made little use of biological information about pattern recognition processes in organisms. At some point, such information might be quite helpful; the fact that the Japanese analysts have not utilized it is an interesting fact itself. So another item for reflection: Just what kind of biological information will be necessary before it is utilized by designers of pattern recognition machinery and software?

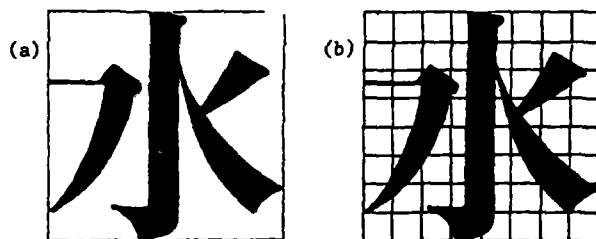


Figure 1. Kanji Character Projected onto 64 Subareas.

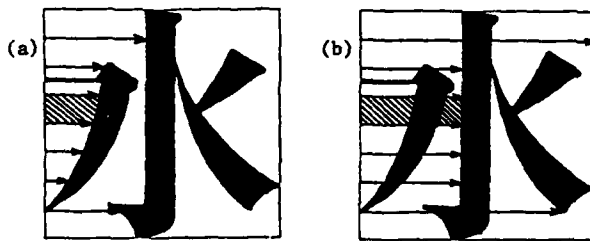


Figure 2. White-to-Black Changes Along a Standard Thin Line.

㇏	一	丨	ノ	㇏	㇏	㇏
㇏	乙	㇏	㇏	㇏	㇏	㇏
㇏	㇏	㇏	㇏	㇏	㇏	㇏
㇏	㇏	ノ	㇏			

Figure 3. Fundamental Kanji Strokes.

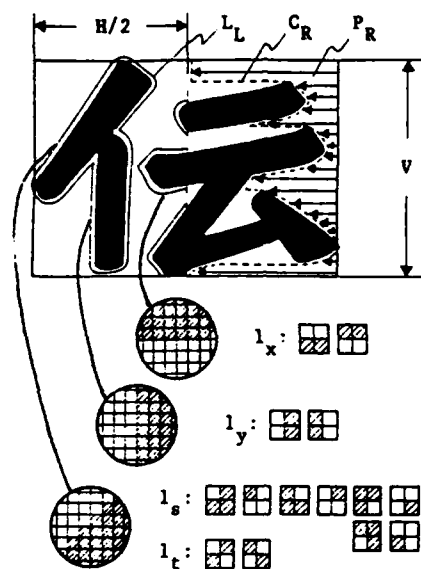


Figure 4. First-pass Scanning Parameters in the Toshiba System.

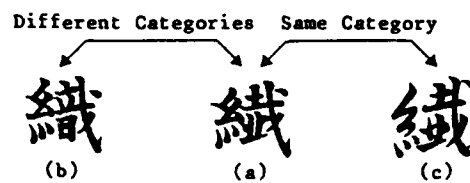


Figure 5. An Example of Pattern Similarity.

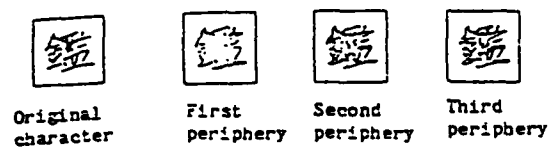


Figure 6. Example of Character Representation as a Function of "Periphery Depth."

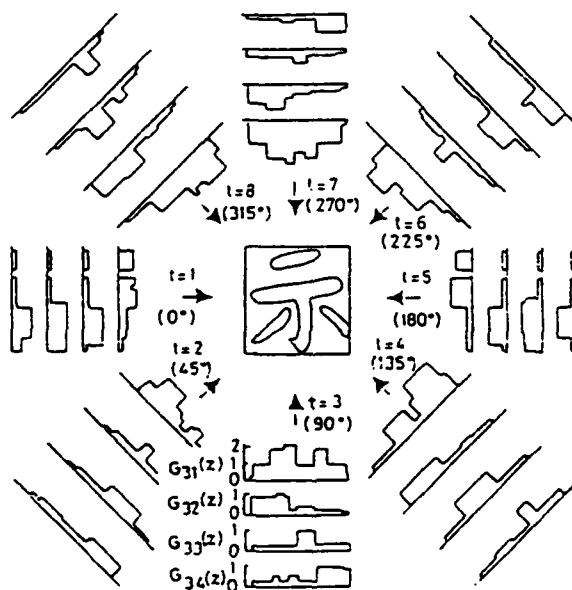


Figure 7. Global Stroke Structure Distributions.

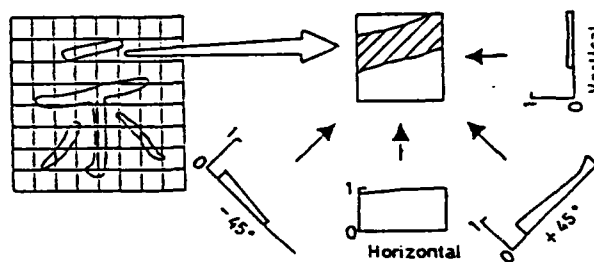


Figure 8. Local Stroke Structure Distributions.

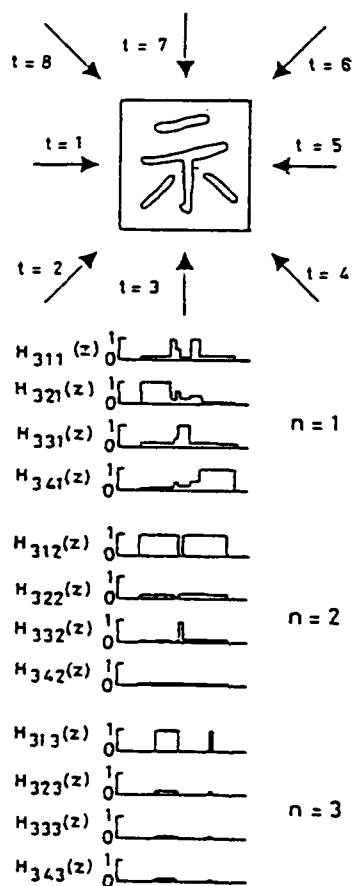


Figure 9. Peripheral Stroke Structure Distributions.

TABLE I.  
DATA SETS USED AT NTT

Data set No.	1	2	3
Kinds of character	Kanji Hiragana Katakana Numeral	Kanji Hiragana Katakana Alphabet Numeral Symbol	Kanji Hiragana
No. of categories	2074	200	881
Writers (persons)	30	200	80
No. of samples	62220	450600	7048
Size of writing box	16 mm square	10 mm square	10 mm square
Size of character array	128 x 128	128 x 128	128 x 127
Writing tool	ball point pen with aquatic ink	mechanical pencil (0.5 mm, HB)	pencil (HB)

#### ACKNOWLEDGEMENTS

Figures 1 and 2 are reproduced from a private communication of the NTT Laboratories at Musashino-shi, Tokyo 180, Japan.

Figures 3, 4, and 5 are reproduced from the *Proceedings of the 6th International Congress on Pattern Recognition*, 1982, IEEE Computer Society, Worldway Postal Center, Los Angeles, CA 90080.

Figure 6, 7, and 8 and Table I are reproduced from an NTT working paper by N. Hagita, S. Naito, and I. Masuda. Available from NTT Electrical Communication Laboratories, Musashino-shi, Tokyo 180, Japan.

# THERMAL MECHANICAL PROCESSING OF STEEL PLATES

Harry I. McHenry

## INTRODUCTION

In the United States, heat treatment is the principal tool of the metallurgist to increase the strength and fracture resistance of steel plates. This is an energy-intensive batch process that follows completion of hot rolling. In Japan, heat treatment is gradually being replaced by increased control of the time-temperature-deformation schedule used for hot rolling, referred to as thermal mechanical treatment (TMT). The result is a continuous process for producing steel plates that have properties in the as-rolled condition that equal or exceed those of heat treated plates. TMT has the added advantage of reducing the alloy content required to achieve a specified property level, and the lower alloy content improves the weldability of the steel. The result: steel plates that are cheaper to make and cheaper to fabricate.

Cheaper and better steel plates are obviously a remarkable technological achievement, but not such a dramatic one. The technology advance has occurred in numerous small increments over a period of about 15 years. The key ingredients have been powerful rolling mills (4000 to 8000 tons capacity is typical) and computerized control of the rolling process. But improvements throughout the steelmaking process have contributed, particularly hot metal desulfurization to reduce inclusion content, improved chemistry control in the basic oxygen furnace, reduced reheat temperatures, and on-line cooling equipment following rolling. [See ONRFE *Scientific Bulletin*, 9 (2) 127, (1983).]

In this report, controlled rolling, accelerated cooling and direct quenching, are discussed. The TMT techniques being used by the five major plate producers are described.

### - Controlled Rolling

The first TMT process was controlled rolling which was introduced in the late 1960s. It was used to produce 500,000 tons of high strength pipe with good toughness at low temperatures for the Trans Alaska Pipeline System. At first, controlled rolling was used almost exclusively for pipe production because relatively thin plate ( $\leq 20$  mm) was used and plate sizes were uniform. However, in the late 1970s numerous advances in controlled rolling were made possible by further metallurgical understanding and the use of process-control computers. It became possible to produce control-rolled plates up to 40 mm in thickness having a variety of sizes for many structural applications including shipbuilding, offshore structures, storage tanks, etc. In the past few years, controlled rolling has been combined with accelerated cooling resulting in improved productivity of the plate mill and further improvements in plate properties.

The main idea in controlled rolling is to condition the austenite to transform to a fine grain ferrite structure, thereby improving strength and toughness. The metallurgical basis for controlled rolling was clarified by Kozasu [*Trans. ISIJ* 367 (1971)] who defined three ranges for austenite deformation:

- Range I: Deformation of austenite above 1000°C is followed by recrystallization and rapid grain growth. The austenite transforms to a relatively coarse ferrite and upper bainite structure. This is the region of conventional rolling.



- Range 2: Multiple pass rolling in the temperature range of 900° to 1000°C refines the austenite grain size by repeated recrystallization. Nucleation occurs at grain boundaries, and thus, a small initial grain size (low slab reheat temperature) results in a finer austenite grain size after rolling. The ferrite grain size is reduced in proportion to the prior austenite grain size.
- Range 3: Deformation of austenite below the recrystallization temperature, below 900°C, creates ferrite nucleation sites within the austenite grains, and leads to a finer ferrite grain size. Microalloying with niobium was shown to be the most effective method of delaying recrystallization, thereby promoting a fine grain size.

Modern controlled rolling practices achieve improved properties by using greater reductions at low temperatures, particularly at temperatures below the austenite recrystallization temperature, i.e., Range 3. Sometimes, rolling is continued to temperatures below the austenite transformation temperature,  $A_{r3}$ . The latter, known as two-phase rolling, continues to increase the ferrite nucleation sites in the remaining austenite and work hardens the ferrite. However, two-phase rolling tends to increase the anisotropy of mechanical properties and promotes the appearance of through-thickness separations (splitting) on fracture surfaces.

The practices used by the Japanese steel companies to produce structural steel plates by the controlled rolling process are summarized in Table I and Figure 1. These processes can be used to produce plates with excellent combinations of strength and toughness; however, there are shortcomings to the controlled rolling process. These include:

- maximum plate thickness is limited to 30-40 mm,
- mill production is reduced,
- through-thickness properties are deteriorated, particularly when two-phase rolling is used,
- code acceptance is limited.

Each of these shortcomings is alleviated by accelerated cooling following controlled rolling. Thus, the trend is toward this type of processing. However, before discussing accelerated cooling, the NIC (Nippon Steel Intercritical Control Rolling) and SHT (Sumitomo High Toughness) processes are described to reveal the potential of cold rolling for improving the properties of structural steels.

The NIC process, shown schematically in Figure 1, retains a fine austenite grain size in the slabs by using an extra-low-temperature reheating (~1000°C), retards grain growth during roughing with fine TiN precipitates, and finish rolls with reductions greater than 40% at temperatures below the austenite recrystallization temperature. Rolling in the two-phase region is avoided or kept to a minimum (less than 20% reduction) to limit anisotropy in the mechanical properties. Anisotropy is further reduced by lowering sulfur content (~0.003%) and using calcium treatment for sulfide shape control. This treatment results in superior low temperature properties for ABS Grade EH36 steel, which is comparable to Navy HTS steel, with a 50 ksi minimum yield strength. For example, the NDT is typically about -100°C and the Charpy impact toughness at -60°C is greater than 60 ft lb. In addition, weldability is excellent with a carbon equivalent less than 0.35. TiN precipitates retard grain coarsening in the heat affected zone, thereby permitting high heat input welding.

The SHT process, shown schematically in Figure 1, involves a two-step rolling process. Roughing is done using conventional rolling practice. The plate is then transferred to a special line, (shown in Figure 2), and cooled below the transformation finish temperature  $A_{F1}$ ; it is then reheated to slightly above the  $A_{C3}$  transformation temperature, about 930°C, and then returned to the rolling line for finish rolling. Strength, toughness, and carbon equivalent are similar to those given above for the NIC process. Despite these excellent properties, the development of accelerated cooling techniques has limited the use of the SHT process to the one facility at Sumitomo Metal Industries, Kashima Works.

#### - Accelerated Cooling

Accelerated cooling after controlled rolling is a new TMT process for the production of steel plates with improved combinations of strength, toughness, and weldability. In this process, the plate is controlled rolled with a finishing temperature of 800° to 900°C. The plate then enters a water spray facility and is cooled at a rate between 3° and 15°C/sec to a temperature lower than 650°C and then air cooled. For C-Mn steels, the idea is to cool fast enough to avoid pearlite formation, and to form a high volume fraction of fine bainite. The resulting plates have properties in the as-rolled condition that equal or exceed those of plates given a normalizing heat treatment. Furthermore, these properties can be achieved with a lower alloy content, and thus the carbon equivalent is lower and weldability is improved.

Accelerated cooling improves the controlled rolling process because the finishing temperatures (above  $A_{F3}$ ) are higher than normally used for controlled rolling, and thus, rolling mill efficiency is increased. In addition, separations (splitting in the through-thickness direction) are virtually eliminated when two-phase (below  $A_{F3}$ ) rolling is not used. The higher rolling temperatures also make it possible to extend the controlled rolling process to thicker gages. The thickness limit for accelerated cooling is approximately 50 mm for C-Mn structural steels.

The microstructure and resultant properties are governed by processing parameters for both controlled rolling and accelerated cooling. Toughness and yield strength are controlled by prior austenite grain size and thus by reheat temperature and controlled rolling practice. Tensile strength is improved by introducing bainite into the microstructure of ferrite plus pearlite that controlled-rolled or normalized products have. To assure bainite formation, the starting temperature should be above the austenite-to-ferrite transformation temperature. Otherwise hardenability, and consequently, strengthening is reduced. The cooling rate should be sufficient to avoid pearlite formation, a cooling rate in excess of 4°C/s is necessary for a 0.12% C, 1.38% Mn steel. Increasing the cooling rate increases the bainite fraction in the microstructure and decreases the ferrite grain size.

The temperature at which accelerated cooling is stopped varies significantly from company to company. At NKK, accelerated cooling is stopped at temperatures between 500 and 650°C. This is referred to as interrupted accelerated cooling. In contrast, Nippon Steel uses continuous accelerated cooling, sometimes to temperatures approaching ambient. There appears to be a trend, however, for all producers to interrupt the cooling cycle at higher temperatures (greater than 400°C), i.e., toward interrupted accelerated cooling. There are several advantages. First, and foremost, the residual stresses in the plate are lower, because the thermal gradients are reduced as the stop temperature is increased. In addition to improving plate flatness, this provides the fabricator with a plate having satisfactory dimensional stability when being torchcut.

Second, the higher finishing temperatures improve toughness of the plates by promoting self-tempering of the bainite. Third, the plate can be hot levelled after accelerated cooling using on-line equipment.

The five largest steel plate producers in Japan have all installed production facilities for accelerated cooling. These facilities are shown schematically in Figure 2. The On-line Accelerated Cooling (OLAC) facility at the Fukuyama Works of Nippon Kokan and to a lesser extent the Continuous On-line Control (CLC) facility at the Yawata Works of Nippon Steel were discussed in the previous issue [ONR *Scientific Bulletin*, 9 (2) 144, (1984)]. The Kobe Steel Controlled Rolling and Cooling (KONTCOOL) facility at the Kakogawa Works is similar to the Nippon Kokan OLAC process except that it is equipped with auxiliary nozzles at the entry end for direct quenching. In this report, the Multipurpose Accelerated Cooling System (MACS) at Kawasaki Steel is described.

The MACS facility was installed at the No. 2 plate mill of the Mizushima Works in April 1983. It consists of an accelerated controlled cooling (ACC) device and a direct quenching (DQ) device, which are arranged in series on the mill line. The ACC and DQ are independent facilities in the sense that one or the other (or neither) is used. For interrupted accelerated cooling, the plate is control rolled, and then subjected to controlled water cooling in the MACS-ACC facility. Subsequently, the plate passes through a hot leveler and is then air cooled. After this brief treatment, the plate has properties that exceed the requirements for normalized plate.

The MACS system features fully automated operation, accurate controls on cooling velocity and finish cooling temperature, and uniform cooling for achieving satisfactory mechanical properties and flatness throughout the plate. The plumbing system features several innovations. There is a separate pumping system to avoid variations in water pressure and a cooling tower to keep the water temperature constant. The cooling system for the ACC has rod-like (i.e., like a faucet rather than a spray) flow nozzles to cool the plate from the top, and curtain-flow cooling from the bottom. The cooling system has quick start and stop characteristics and electromagnetic flow meters to control the flow rate over a wide range. To assure uniformity of cooling, the upper nozzles are staggered and equipped with a flapper device that disperses the water flow at the beginning of the cooling cycle, i.e., cooling is initially by a uniform spray and then by the more efficient rod-like flow. To minimize lateral temperature variations, the top header is divided into edge, quarter-width, and center zones. The flow in each zone is adjusted to assure uniform cooling, i.e., more in the center and less at the edge due to the lateral flow direction. Furthermore, a gutter system is used to mask the plate edges and prevent local overcooling.

The ACC system is fully automated. First, there is a mechanical property model that determines the optimum values of cooling velocity and finish cooling temperature for achieving the specified mechanical properties, particularly tensile strength (note: for a given chemistry, toughness and yield strength are governed primarily by controlled rolling practice). Given the desired cooling conditions, there are process-control computer models to assure accurate temperature control (top and bottom water volume, table speed, stop time, etc.) and uniform cooling in the transverse direction (top-header zone control, edge gutter setting, flapper controls, etc.). The result is a tailor-made processing history (similar models exist for controlled rolling) for each plate intended to provide a consistent quality level that exceeds specified requirements.

### - Accelerated Cooling--Fabricator's Viewpoint

Accelerated cooled plates have been widely used for structural applications over the past two years. The principal shipyards have evaluated plates produced to the requirements of the ABS higher strength steel grades, EH32 and EH36 (yield strengths of 45 and 51 ksi, respectively). The evaluations have led to numerous applications in shipbuilding and offshore structures.

The results indicate that the higher strength grades have fabrication characteristics that are comparable to those of ordinary strength carbon steel. Specifically, accelerated cooling relaxes requirements for preheating, reduces the minimum weld length requirements for tack and repair welding, reduces the requirements for low hydrogen electrodes and permits higher temperatures to be used for flame strengthening.

A comparison of the welding procedures used for conventional steels versus TMT steels was provided by Mitsui Zosen for the case of EH32. Preheating is generally required for EH32, the level depending on the carbon equivalent,  $C_{eq}$ . In the case of TMT steels with  $C_{eq} \leq 0.36\%$ , preheat is unnecessary providing the temperature is over  $0^{\circ}\text{C}$  and low hydrogen electrodes ( $\leq 5 \text{ cc/100g}$ ) are used for butt welding. The minimum length of tack and repair welds can be reduced from 50 mm (for conventional steel) to 10 mm for TMT steel providing the  $C_{eq}$  is less than 0.34% and low hydrogen electrodes are used. The baking requirements to control hydrogen are relaxed in terms of baking temperature, holding temperature, and exposure time. The baking temperature is reduced from  $300\text{--}350^{\circ}\text{C}$  (conventional) to  $70\text{--}100^{\circ}\text{C}$  (TMT); a 30 to 60 min cycle is required in both cases. The holding temperature is reduced from  $100\text{--}150^{\circ}\text{C}$  to  $70\text{--}100^{\circ}\text{C}$ . The exposure time was increased from 4 to 8 hr. Gravity welding, which is commonly used for fillet welding of subassemblies in the flat position, normally requires the use of low hydrogen electrodes, but with TMT steels ( $C_{eq} \leq 0.36\%$ ), high hydrogen ( $\leq 30 \text{ cc/100g}$ ) electrodes can be used. Finally, the temperature limits on flame strengthening have been increased from  $650$  to  $850^{\circ}\text{C}$  when followed by air cooling to  $600^{\circ}\text{C}$  and then water cooling. Each of these changes reduces costs of ship construction with no sacrifice of quality. Apparently, similar results are being obtained by other shipyards and by the SR193 committee of the Japan Shipbuilders Research Association. As a result of these findings, the TMT steels have found broad acceptance by the shipbuilding industry over the past two years.

### - Direct Quenching

The latest development in TMT is direct quenching. In this process, controlled rolling is followed by a direct quench using on-line equipment. In conventional processing, the plate is cooled after rolling and then reheated and quenched using off-line facilities. The same tempering treatment is used for both processes. Elimination of the reheat/quench cycle results in a considerable cost savings. Furthermore, direct quenching improves the hardenability of steel and thus permits a reduction in alloy content to achieve specified properties. In turn, the reduced alloy content lowers the carbon equivalent and weldability is improved.

The controlled rolling that precedes direct quenching starts at temperatures below  $1100^{\circ}\text{C}$  (i.e., low reheat temperature) and finishes above the austenite recrystallization temperature. Thus, finishing temperatures in excess of  $850^{\circ}\text{C}$  are typical. This results in a fine grained equiaxed austenite microstructure. Direct quenching must be started at temperatures above  $A_{r3}$ , i.e., about  $800^{\circ}\text{C}$ . Thus, there are narrow temperature ranges for both roughing and finishing. There is a lower limit on thickness of about 16 mm due to these limited temperature ranges and due to flatness problems associated with quenching.

The maximum thickness is limited by the controlled rolling process and hardenability considerations; the current limit for HT70-HT100 class (yield strengths of 80 to 130 ksi) steels is 75 mm at Sumitomo. However, research is underway to extend this limit to 150 mm.

Production equipment for direct quenching has been installed at the Kashima Works of Sumitomo and the Mizushima Works of Kawasaki Heavy Industries, (see Figure 2). In addition, Kobe Steel has installed heavy cooling nozzles on the front end of their KONTCOOL facility that are capable of producing sufficient cooling rates for direct quenching. The author is not aware of the direct quench capabilities of NKK or Nippon Steel; apparently these companies do not have production facilities specifically for direct quenching.

The direct quenching facilities of Kawasaki and Sumitomo are continuous quenching devices, i.e., the plate is quenched progressively as it passes through the quench facility. Sumitomo uses a Dreaver-type roller quench facility, i.e., the plate is held by rollers and water sprayed (top and bottom) as it passes through the unit. Kawasaki uses the roller hold down concept, but floods the portion of the plate being quenched. The cooling water is stirred with paddle rollers that continually move water over the plate. High velocity slit nozzles are used at the entrance and exit of the cooling zone to prevent slack quenching due to water flowing over the plate prior to entering the cooling zone.

Kobe Steel is considering adding heavy cooling nozzles along the complete length of the accelerated cooling unit. This would permit simultaneous direct quenching of an entire plate rather than continuous quenching. Simultaneous quenching offers the potential for reducing the alloy content because optimum quenching conditions can be achieved throughout the plate. The water requirements for simultaneous quenching are quite large, and thus the additional facility requirements are nontrivial.

Sumitomo has been the leading user of the direct quench process with production experience in excess of 50,000 tons. Several research investigations relating to direct quenching were described to the author by Sumitomo researchers. In the development of HT60 grade for low temperature service (LPG tanks) a high nitrogen content (0.007% N 0.003% N) was found to reduce the hardenability of HT60 steel. This was attributed to the precipitation of  $AlN$ , which forms sites for ferrite nucleation and results in a serious degradation of impact properties. Thus, the maximum nitrogen content was limited to 0.004%. The chemistry, manufacturing conditions and expected mechanical properties are summarized in Table 2. Note that this steel has expected properties that meet HY80 requirements and yet the carbon equivalent (IIW) is less than 0.40% ( $P_{Cm} = 0.18$  to 0.20). Thus, little or no preheat is required for welding.

Sumitomo has also developed an HT80 alloy (comparable strength to HY100) that has a substantially reduced alloy content and thus, improved weldability. The alloy reduction is made possible by the hardenability improvements due to direct quenching and low nitrogen (0.0035 max). The weld heat-affected-zone toughness is also improved by reductions in nitrogen, molybdenum, and silicon. The chemistry and mechanical properties are summarized in Table 3.

#### SUMMARY COMMENTS

Thermal mechanical processing of steel plates has been used since the late 1960s for the production of line pipe steels. Millions of tons of steel have been controlled

rolled to meet the requirements of API 5LX65 and X70 for large diameter pipe. However, the use of controlled rolling for the production of steel plates has been limited because of reduced mill efficiency, plate thickness limitations, deterioration of through-thickness properties and lack of code acceptance. These shortcomings have been alleviated by accelerated cooling following controlled rolling. As a result, TMT plates are now being used in numerous structural applications. There has been widespread usage of accelerated cooled plates by Japanese shipyards over the past two years, and the user experience has been positive. These steels have strengths comparable to heat treated grades and weldability comparable to plain carbon steels. More recently, direct quenched steels have been developed to replace quench-and-tempered high strength steels. Since this represents only 5% or so of the plate market, the user experience is still somewhat limited. However, results of research by the steel industry suggest that direct quenching can lead to remarkable improvements in hardenability and thereby decrease alloying requirements. This in turn leads to improved weldability. Cost reductions associated with continuous processing and improved weldability should lead to greater applicability of the direct quenched steels.

Accelerated cooling should be of particular interest to the U.S. steel industry because of its cost reduction potential, broad applicability, and moderate capital investment requirements. In particular, the relatively high finishing temperatures permit use of lower force-capacity rolling mills than required for conventional cold rolling.

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TABLE I  
CONTROLLED ROLLING PRACTICES  
USED BY JAPANESE STEEL COMPANIES

COMPANY	PROCESS NAME	TYPE (See Figure 1)
Kawasaki Steel	SCR	2
Kawasaki Steel	KTR	3
Kobe Steel	KONTROLL	3 or 2
Sumitomo Metal Industries	SHT	4
Sumitomo Metal Industries	SSC	2
Nippon Steel	NIC	1
Nippon Kokan	NCT	3

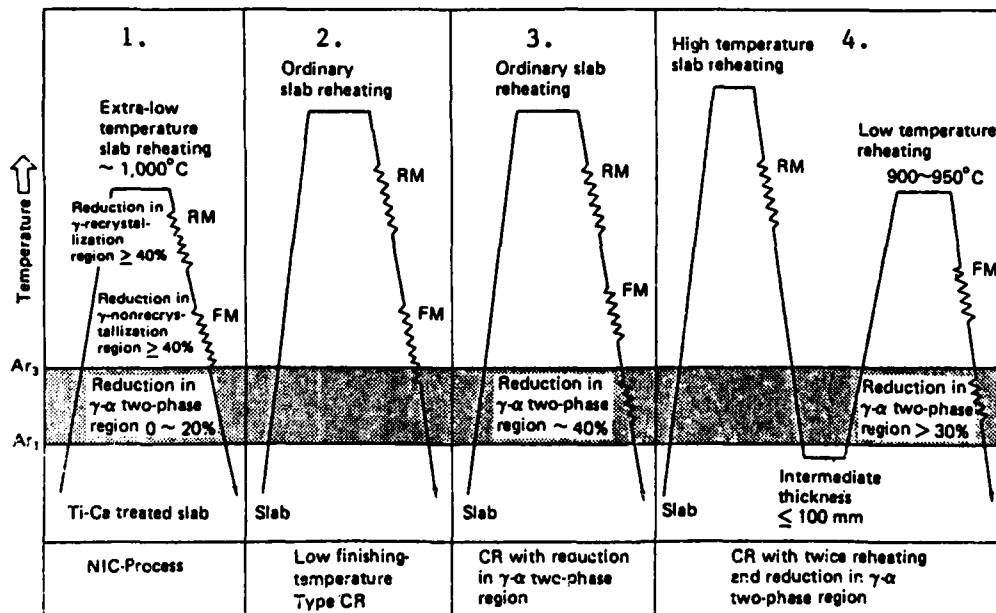


Figure 1. Comparison of Various Types of Thermal Mechanical Controlled-rolling Processes. [From Nippon Steel Report, (1982)].

Note: Sumitomo's SHT process is on the right.

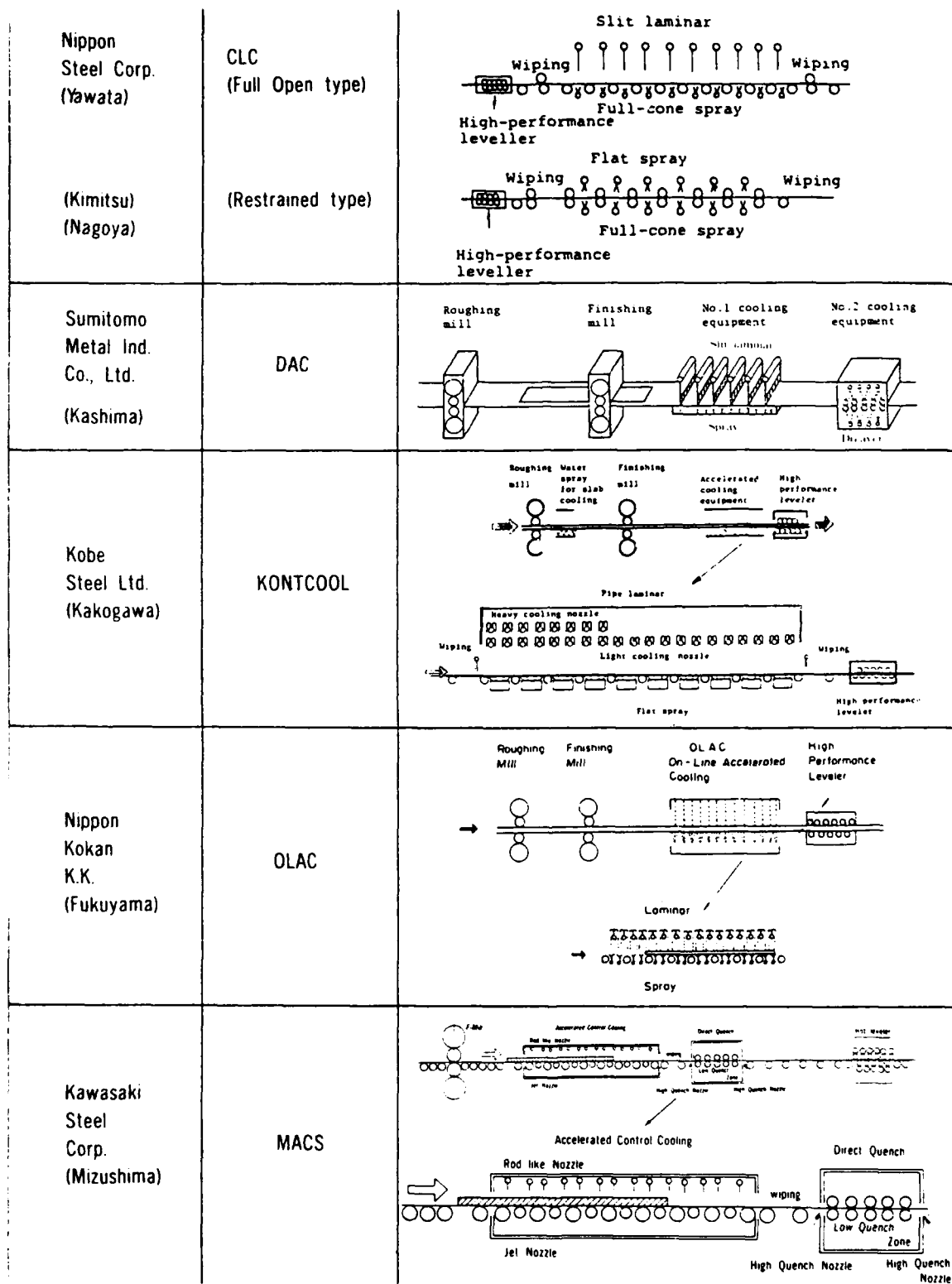


Figure 2. TMT Facilities in Japan. (Courtesy of *Nippon Kaiji Kyokai*).

TABLE II  
SUMITOMO'S HT60 STEEL FOR LPG TANKS  
PRODUCED BY THE DIRECT QUENCH PROCESS

Chemical compositions

C	Si	Mn	P	S	Cu	Ni	V	sol.Al	N	Ti	P <sub>cm</sub>
0.08 / 0.10	0.15 / 0.22	1.30 / 1.40	≤0.015	≤0.003	0.20 / 0.30	0.50 / 0.60	0.02 / 0.04	0.025 / 0.055	≤0.0040	0.003 / 0.007	0.118 / 0.20

Manufacturing conditions

Reheating temperature (°C)	1100 ~ 1150
Finishing temperature (°C)	900 ~ 930
Tempering temperature (°C)	630

Mechanical properties (predicted), for 38 mm thick plate

Yield Strength	Tensile Strength	Charpy Impact
YS (ksi)	TS (ksi)	vTs (°C)
85	95	-100

TABLE III  
SUMITOMO'S HT80 STEEL PRODUCED BY THE DIRECT QUENCHING PROCESS

Steel	C	Si	Mn	Cu	Ni	Cr	Mo	V	B	N	P <sub>cm</sub>	C <sub>eq</sub>
Developed	0.10	<0.10	1.10	0.25	-	0.85	0.20	0.04	0.0008	≤0.0035	0.235	.51
Ordinary	0.11	0.27	0.79	0.18	1.06	0.48	0.45	0.03	0.0014	-	0.249	.51

Steel	Baseplate (38 mm)		Preheat temp. (°C)	Welded joint SAW 45 kJ/cm					Welded joint SAW 60 kJ/cm				
	TS (ksi)	vTs (°C)		TS (ksi)	vTs (°C)	vE-30 ft.-lb.	T <sub>6C</sub> =0.1 (°C)	TS (ksi)	vTs (°C)	vE-30 ft.-lb.	T <sub>6C</sub> =0.1 (°C)		
Developed	120	-106	<75	117	-22	66	-29	118	-15	30	-18		
Ordinary	120	-105	<100	116	-15	36	-17	118	-1	32	-8		

T<sub>6C</sub>=0.1: The temperature at which δ<sub>C</sub> = 0.1 mm in CO<sub>2</sub> test  

$$C_{eq} (IIW) = C + \frac{Mn}{6} + \frac{Cu+Ni}{15} + \frac{Cr+Mo+V}{5}$$

## NARROW GAP WELDING IN JAPAN

Harry I. McHenry

### INTRODUCTION

Narrow gap welding is a technique for making welds in a square-groove joint in thick materials. The gap between the plates to be welded is typically 10 to 20 mm for plate thicknesses up to 300 mm. The gap is filled with successive layers of weld metal, with a constant number (usually one or two) passes per layer. Each layer is about a third of the joint gap in thickness. Automatic arc welding processes are used to fill the joint; specifically these processes are gas metal arc welding (GMAW), submerged arc welding (SAW), and gas tungsten arc welding (GTAW).

Narrow gap welding is a concept that was developed in the U.S. and subsequently modified, improved and commercially applied in Japan. Numerous process variations are used in Japan as summarized in Figure 1. Many of these processes are of potential interest to American companies and to U.S. Navy shipyards as evidenced by a recent workshop (June 1984) on narrow gap welding sponsored by the American Welding Technology Application Center. The following report was prepared to review the state-of-the-art of narrow gap welding in Japan.

### GAS METAL ARC WELDING--NARROW GAP, (GMAW-NG)

Gas metal arc welding (GMAW) is the most commonly used process for narrow gap welding. The GMAW-NG process was first developed by Battelle in the early '60s and subsequently adapted to pressure vessel manufacture by Mitsubishi Heavy Industries (MHI) in the mid-60s. In the MHI procedures, the torch is positioned above the narrow groove and a relatively large diameter (3.2 mm) wire is fed into the groove. The wire is sufficiently stiff to maintain a central position in the groove and a high current density is used to assure adequate sidewall penetration. Variations of this process, including the use of flux cored wire, were used in the early '70s for the construction of tall buildings.

In the mid-70s, several process innovations were introduced and the GMAW-NG process became more widely used. A nozzle was developed that fits within the narrow gap such that the contact tube and the gas coverage are close to the weld pool. Arc oscillation techniques were developed that provided good sidewall fusion, but did not require oscillation of the nozzle. Numerous variations of these ideas have been developed and put into production over the past ten years. The main features of these processes are that one pass per layer welds are built up within a narrow groove (typically  $12 \pm 2$  mm wide) using small diameter wire (1.2 mm). Successive layers, with a height less than half the groove width, are used to fill the joint. Many variations of the GMAW-NG process are discussed in the following subsections.

#### - Bent Wire Processes

The recurring problem of lack-of-fusion limited the applications of narrow gap welding by the Battelle and MHI processes. This problem was overcome by developing means of oscillating the arc within the confines of the narrow groove where torch oscillation is severely limited. The idea is to bend the wire in a controlled manner just prior to its entering the nozzle such that it swings back and forth upon exiting the nozzle. The swinging wire causes the arc to oscillate across the groove and to impinge

upon the sidewalls thus assuring good penetration. This idea was developed by Hitachi Zosen in 1975. In the Hitachi Zosen process, a spiral cast was imparted to the wire by a rotating mechanism located above the nozzle. Upon exit from the nozzle, the wire traversed a circular path. This development was followed in rapid succession by process variations developed by Babcock Hitachi, Nippon Steel Company, and Mitsubishi Heavy Industries. The bent wire approaches are shown schematically in Figure 2.

Of the various bent wire approaches, the Babcock-Hitachi method has achieved the highest market share with approximately 100 units in use throughout Japan. Several models are marketed by Hitachi Seiko, including a small track-mounted unit and larger units that are mounted on a side beam. One side beam unit features tandem electrodes to improve deposition rate. A schematic view of the Babcock-Hitachi process is shown in Figure 3. The wire bending mechanism is an oscillating panel that swings back and forth while the wire is being fed into the nozzle by the wire feed rollers. The wire exits the torch oscillating laterally, and thus the arc oscillates from side to side in the groove assuring side wall penetration. The torch has shielding gas nozzles before and after the wire guide, through which gas is blown into the molten pool with sufficient force to assure a semicircular bead contour and to prevent air from being drawn into the puddle vicinity. Secondary shielding nozzles are located at the plate surface to prevent air from entering through the top of the groove. To prevent burn back, a pulsed-power supply operating in the short-arc spray-transfer mode is used.

The four bent wire approaches shown in Figure 2 operate using similar welding parameters, joint preparations, and gas shielding techniques. Typical parameters are summarized in Table I. Note that each process uses dc reversed polarity, pulsed power, and mixed gas (argon plus 20% CO<sub>2</sub>). Each process features a unique bending approach and thus different arc oscillation characteristics result. For example, in the Hitachi Zosen process, the arc has a circular motion; in the Nippon Steel process, the arc swings back and forth with an adjustable dwell time at each side; and in the Mitsubishi Heavy Industry process there is an adjustable bending mechanism that permits many variations in arc oscillation. It is not clear to the writer which, if any, of these oscillation patterns is preferable.

#### - Twist Wire Method

Concurrent with the development of the bent wire approaches, a novel method of achieving arc oscillation was developed by Kobe Steel. Two wires were simply twisted together to form a single composite wire. As the twisted wire burns, the tip position constantly changes causing a circular oscillation of the arc. Thus, arc oscillation is achieved without any special bending devices, and conventional GMA welding equipment (with SAW wire feeders) can be used. For gas shielding, Kobe Steel has a special nozzle design to provide fore and aft coverage near the weld pool and secondary protection at the plate surface. The welding parameters for the twist wire method are compared to those of other GMAW-NG methods in Table I. Note the 2 mm diameter of each wire; the effective diameter of the two-wire composite is significantly greater than the 1.2 mm diameter wire used in the bent wire processes. Thus, the welding current and heat input are considerably higher. A wider gap (14 mm *vs.* 10 mm) is used, and thus more wire is required to fill the joint. With the higher current and travel speed, the fill rate of the Kobe process exceeds that of the bent wire processes--despite the wider gap.

The main advantages of the twist wire process are its adaptability to conventional welding equipment, the high joint completion rate, and deeper sidewall penetration

associated with higher current operation. Disadvantages stem from the use of twisted wire, i.e., it is more expensive, the availability for certain grades is limited, and code approval may be required for certain applications. Also being a higher heat input process, the impact properties of the welded joint may be lower for certain alloy steels and steels for low temperature service.

#### - Rotating Arc

The rotating arc process developed by Nippon Kokan (NKK) is a third approach to arc oscillation without oscillation of the torch or nozzle. It is the only narrow gap welding system in use with an automatic seam tracking system based on arc sensing. The main features of the process are shown in Figure 4. Circular movement of the arc is accomplished by rotating a welding nozzle with an eccentric guide hole. The arc rotates at an extremely high speed; 100 revolutions per second around a 7 mm diameter is typical.

The welding parameters are similar to those shown in Table I for the bent wire processes. However, NKK reports that higher current operation is possible due to a reduced level of penetration in the center of the groove which reduces the tendency of center line hot cracking.

The arc sensing system used with the rotating arc process provides automatic seam tracking capability. The vertical and lateral control of the torch position is achieved by sensing the arc voltage which is a function of arc length. The lateral position of the torch is adjusted by automatic feedback control such that the voltage change as the arc approaches the left wall is the same as the voltage change as the arc approaches the right wall. Vertical control is achieved by controlling the arc voltage level which is a function of the distance between the electrode and the puddle. The response rate of the servo-controlled guidance system is sufficient to permit tracking on inclined planes and curved joints.

The rotating arc system is used by NKK at the Tsu and Tsurumi Works; however, it is not yet commercially available and thus user experience is limited. The apparent advantage is, first and foremost, the seam tracking capability. Beyond that, the use of straight wire eliminates problems associated with wire bending, i.e., different types and batches of wire may have different response to bending, and contact-tip wear is aggravated by the spring forces of the wire against the tip.

#### - Straight Wire

The first narrow gap welding procedure used in Japan was developed by Mitsubishi Heavy Industries in 1966 and is still being used to weld boiler headers in thicknesses up to 130 mm. A relatively large diameter wire (3.2 mm) is fed straight into the groove; there is no arc oscillation. The arc column is spread by use of the large diameter wire and pulsed current, and thus, sidewall penetration is satisfactory. The welding parameters are compared with those of other GMAW-NG procedures in Table I. Note that the gap is wider (16 mm) and the current and heat input are moderately high. MHI is currently developing a tandem torch modification of the process in which the two electrodes are directed towards the opposite sidewalls resulting in a two bead/layer weld. The deposition rate is nearly double that of the single wire process. This process has been developed at the laboratory level (Nagasaki Technical Center), but it has not yet been used in production.



Other GMAW-NG processes have been developed using straight wire, but these processes have not been observed by the author. Two such approaches oscillate the electrode wire with a synchronized change of the welding current and voltage: the Skip-Arc Process developed by Kobe Steel and the Capsul System developed by Kawasaki Heavy Industries. Both of these developments were made in the mid-70s and may have been superseded by other methods.

#### - Flux Cored Wire

Sumitomo Metal Industries has developed welding equipment and consumables for out-of-position narrow gap welding by the GMAW process. The author observed this equipment at the International Welding Exposition in Osaka. Flux cored wires, CO<sub>2</sub> gas coverage, and backing tapes like those used for one-side welding are used. For horizontal position welding, an ac power source and a special flux-cored-wire with a 2 mm diameter is used. The cross section of this wire, shown in Figure 5, is said to improve arc stability under ac operation. The process is suitable for welding thicknesses in the range of 25 to 80 mm. A variety of joint configurations have been evaluated in an effort to overcome a characteristic problem with undercut at the lower sidewall. A 4-7 mm rootgap with a square joint prep on the lower plate and a 20° bevel on the upper edge is recommended for use with a backing tape. For vertical welding, dc power and a conventional 1.2 mm-diameter cored wire (See Figure 5) is used. The thickness for vertical welding is limited to 25 mm, and thus, this process is suitable for thinner applications than normally considered for narrow gap welding.

For flat position welding, ac power and the special flux cored wire (Figure 5) with a diameter of 2.4 to 3.2 mm is used to narrow gap weld thicknesses in the range of 50-120 mm. No details regarding this process were available to the author.

The available consumables for the Sumitomo fluxed-cored system are limited to the following types of steels at the present time: mild steel, HT50 (tensile strength = 70 ksi) and HT60 (tensile strength = 85 ksi).

#### SUBMERGED ARC WELDING--NARROW GAP, (SAW-NG)

The submerged arc welding (SAW) process is widely used for welding heavy section steel structures and vessels because of its high deposition rate, consistent quality level and ease of automation. Its use for narrow gap welding has been limited by the problem of slag removal from within a deep, narrow groove. Recently, several Japanese companies have developed fluxes especially formulated for narrow gap welding. These fluxes feature good detachability characteristics owing to their high coefficient of thermal contraction upon cooling and the weak bonding force between the slag and the metal. In addition, slags promote the formation of a concave weld bead without undercut. Used with appropriate filler metals, welds that are free of hot cracking and other defects and that have satisfactory mechanical properties can be consistently obtained.

The SAW-NG process uses conventional SAW welding equipment, including in certain cases, tandem (two) electrodes. Special nozzles such as the one shown in Figure 6 may be used to guide the wire and flux to the bottom of the groove. Typical welding parameters are shown in Figure 7.

Two bead sequences are commonly employed: one pass per layer and two passes per layer. The one pass per layer technique permits use of narrower grooves; however, a

number of precautions are necessary when applying this technique. The electrode must be centered within  $\pm 1.5$  mm and the welding parameters must be selected to assure optimum penetration of both sidewalls. Too much penetration may undercut the sidewalls and too little may result in incomplete fusion. In both cases, slag removal problems are great and slag may be trapped by the next weld pass. Care must also be taken during the first pass to avoid hot cracking. In general, reduced heat input is used for the first pass or passes. When tandem electrodes are used, the first pass is put in with a single electrode.

The two pass per layer technique is less efficient than one pass per layer, but the ease of welding is improved considerably and the heat input is reduced. A wider range of welding parameters can be used because it is not necessary to bridge the gap and sidewall fusion is assured by direct impingement of the arc on one sidewall at a time. Thus, in many production applications the two pass per layer technique is more practical.

The special fluxes with improved detachability have been developed by Nippon Steel, Kawasaki Steel, and Kobe Steel. There are two main types: an acid flux used for welding carbon steels and a basic flux used to weld the higher strength steels and alloy steels. Electrode/flux combinations exist for carbon steel and for several alloy steels including ASTM grades A533B, A387, and A302B. However, the applicability is sometimes limited by the availability of code-approved consumables.

#### GAS TUNGSTEN ARC WELDING--NARROW GAP, (GTAW-NG)

The gas tungsten arc welding (GTAW) process can be used to make high quality welds in almost all metals and alloys. However, due to its low deposition rate, it is rarely associated with heavy section welding. Narrow gap welding, with its reduced joint volume, extends the applicability of the GTAW process. It is particularly useful for out-of-position welding and welding of high strength steels and specialty alloys. In addition, GTAW is sometimes used to weld the root pass for narrow gap welds in heavy sections that are subsequently filled by the GMAW-NG or SAW-NG process.

The GTAW-NG process is often used for making particularly difficult welds. Thus, the conditions may vary considerably from one application to another. For example, the hot-wire GTAW process is used to weld stainless steel pressure vessels in the vertical position.

The welding torch design, joint preparations, and welding parameters are shown in Figure 8. Note that double gas shielding is used. One or two passes per layer may be used, although one pass per layer is preferred because it results in significantly less distortion.

The GTAW-NG process for welding HT80 steel (100 ksi yield strength) for pressurized hull structure is shown in Figure 9. Here, the part was considerably thicker than the stainless vessel (100 mm vs. 50 mm) and welding was from one side. Typical welding parameters are summarized in Figure 9. Two or three passes per layer are used, including one pass directed at a slight angle ( $\sim 3^\circ$ ) to each sidewall to assure adequate penetration. Gas shielding is very important for the prevention of porosity. For deep grooves ( $>15$  mm), triple shielding is used, i.e., the tungsten electrode is shielded through the torch, there are fore and aft gas shielding nozzles in the groove, and there is a gas shielding box at the plate surface. Argon gas is used at flow rates as high as 150 l/min.

## OBSERVATIONS AND USER COMMENTS

During the past year, the author has visited numerous factories and industrial laboratories in Japan. Many of these companies were using narrow gap welding in production or in laboratory studies. Selected comments are discussed below.

### - Process-Selection

The most widely used process for narrow gap welding is GMAW-NG. This is, however, partly for lack of alternatives. GTAW-NG is a low deposition rate process and thus not competitive for routine jobs, and SAW-NG was not practical until the recent development of slag systems with good detachability. The current trend appears to be toward more use of SAW-NG because it is easier to use and less susceptible to weld defects such as lack of fusion and porosity. The preference for SAW-NG is most prevalent for welding of carbon steels, where the higher heat input is of little consequence. For alloy steels, GMAW-NG is still preferred by many fabricators because of the lower heat input, a wider range of available consumables, and greater code approval.

The technical literature often states that GMAW-NG is an all position process. This may be true in the laboratory but it is not the case in the welding shops visited by the author. In practice, GMAW-NG is limited to the flat position. For out-of-position welding, the GTAW-NG process is preferred. The GMAW-NG process is potentially useful, particularly the flux-cored wire approach developed by Sumitomo. Although the Babcock-Hitachi GMAW-NG process has been used by that company for out-of-position welding, the commercially available unit marketed by Hitachi Seiko is limited to flat-position welding. Similarly, all of the other GMAW-NG processes, except the flux-cored one, are limited to the flat position.

At the Yokohama Works of Ishikawajima-Harima Heavy Industries (IHI), the SAW-NG process has been used to weld pressure vessel and steel structures for five years. The SAW-NG process is preferred over GMAW-NG because it is less sensitive to weld defects, particularly lack of fusion. During my visit, SAW-NG was being used to weld 250 mm thick carbon steel plate (ASTM A516) for bridge construction. A tandem electrode system was used with a dc lead with arc voltage control for vertical positioning of the electrode and an ac trailing electrode for higher deposition. A double U-groove joint preparation, 100 mm deep per side with a 2° included angle and a 5 mm root radius was used, i.e., the plate was flipped after welding the first side and welding was then completed. One pass per layer technique was used. For joint grooves deeper than 100 mm, a two pass per layer technique is used. A mechanical seam tracking device, consisting of a pair of wheels (like abacus wheels) which sense the position of each sidewall, is used to center the electrode in the groove. IHI also uses the SAW-NG process for nuclear pressure vessels. Here an older procedure is being used pending approval of procedures similar to those used for bridges and chemical plant pressure vessels. A two pass per layer, single electrode (3.2 or 4 mm in diameter) procedure is used with a wider joint preparation, 7 mm root radius and 6° included angle.

At the Tsurumi Works of Toshiba Corporation, all three narrow gap processes are being used. The SAW-NG process is used whenever possible. The example shown to me was a 2 m-diameter hollow shaft for a hydroelectric plant with a 170 mm thick wall. The GTAW-NG process is used for out-of-position welding; e.g., the vertical and horizontal joints in reactor internals made of stainless steels. The LOOPNAP GMAW-NG process is used for welding a 2½ Cr-1 Mo vessel intended for high temperature service; in this case approved consumables were not available for SAW-NG welding.

At the Tsurumi Works of Nippon Kokan (NKK), the SAW-NG process is used for welding carbon steel, high tensile steels and steels for low temperature service. The GMAW-NG process is used for selected applications. For example, circumferential joints in a heavy wall pipe were being welded by the SMAW-NG process and the flanges were being welded to the pipe by the GMAW-NG process. For the circumferential joints, slag removal was no problem because of the exposed joint. However, the flange-to-pipe joint required removal of the slag from an enclosed groove and thus GMAW-NG was preferred. NKK is the developer of the rotating arc GMAW-NG process. At the Tsurumi Works, this replaces the twist arc process and lowers the cost of filler metal. At the Tsu Works, the rotating arc process replaces the LOOPNAP process; problems associated with contact-tip wear and batch-to-batch variations in wire bending are avoided.

Other narrow gap applications observed were:

- two pass per layer SAW-NG process used by Japan Steel Works for vessels up to 400 mm thick,
- the twist arc GMAW-NG process was used by the Hitachi Works of Hitachi,
- the Takasago Works of Kobe was planning to use the SAW-NG process for welded crankshafts (Barminster type, Copenhagen) for marine engines.

#### - Operator Skill

The principal disadvantages of narrow gap welding relate to the high degree of skill needed to successfully apply the process. First, assembly and fit-up must be to high tolerances particularly for GMAW-NG and one-pass-per-layer SAW-NG welding. For these cases, variations of the gap width greater than  $\pm 1$  mm and variations of the electrode position more than 1 mm off center require adjustment in the welding parameters to assure a sound joint. Thus, the operator must be constantly observing the weld and making minor changes as required. For the case of SAW-NG, these observations are made before and after each pass. For GMAW-NG, the arc is monitored visually, usually with the aid of a viewing screen or TV monitor; manual adjustments are made as the weld is being deposited. The operator also serves as an in-process inspector. This is an essential duty because repair welding, except for minor cleanup of the preceding pass, negates the benefits of narrow gap welding. Major repairs must be made using conventional joint preparations and repair welding procedures.

#### - Seam Tracking

At the present time, narrow gap welding is in the incongruous position of being an automatic welding process that requires a high degree of operator skill. The problem stems from the current state-of-development of lateral seam tracking devices. Mechanical contact systems that sense the sidewall of the groove are adequate for keeping the electrode centered in the groove at the position of sensing. However, variations in the groove dimensions and the bead height require a sensing device at the arc.

The most promising approach appears to be an arc-sensing system based on the current (or voltage) versus position with respect to the sidewall. This approach has been developed for the rotating arc GMAW-NG system, but is not yet available for any of the other narrow gap processes. A second approach, observed in the Hitachi Zosen laboratory at Ariaki, uses a fiber optic video monitor to display the arc on a TV screen, and

automatic feedback controls based on light intensity variations about a central reference line. A similar video system coupled with audio monitoring, was under development at the IHI Welding Institute. This appears to work well in the laboratory, but there are doubts about the durability of the arc-viewing system in production.

## SUMMARY

The narrow gap welding process is being widely used in Japan for welding heavy section steels. The GMAW-NG process is most commonly used; however, with the development of new flux systems, the SAW-NG process is becoming more popular. With only a few exceptions the GMAW-NG and SAW-NG processes are limited to welding in the flat position. For out-of-position welding, the GTAW-NG process is preferred.

The advantages and disadvantages of the narrow gap welding processes stem directly from the narrow gap joint preparation. On the positive side, welding time is reduced, fewer consumables are required, and distortion is lower. Moreover, the energy input is lower, and thus the mechanical properties, particularly fracture toughness, are improved. The main disadvantages of the narrow gap welding processes are the close tolerances on assembly, the high degree of operator skill required, and the difficulty of making repairs.

Future developments of the narrow gap welding process are in progress at numerous laboratories. High priority developments include seam tracking, real time process control monitors, and improved repair welding procedures. In addition, improved consumables are under development to extend the use of the SAW-NG process to more steel grades and alloy systems, to develop out-of-position capability for the GMAW-NG process, and to raise the deposition rate of GTAW-NG welding.

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Hitachi Seiko, Ltd.

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Chief Welding Engineer  
Ariake Works  
Hitachi Zosen

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Technical Research Institute, Sakai  
Hitachi Zosen

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Materials Research Laboratory, Muroran  
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Senior Researcher, Welding Technology Laboratory  
R&D Laboratories-II, Sagamihara  
Nippon Steel Corporation

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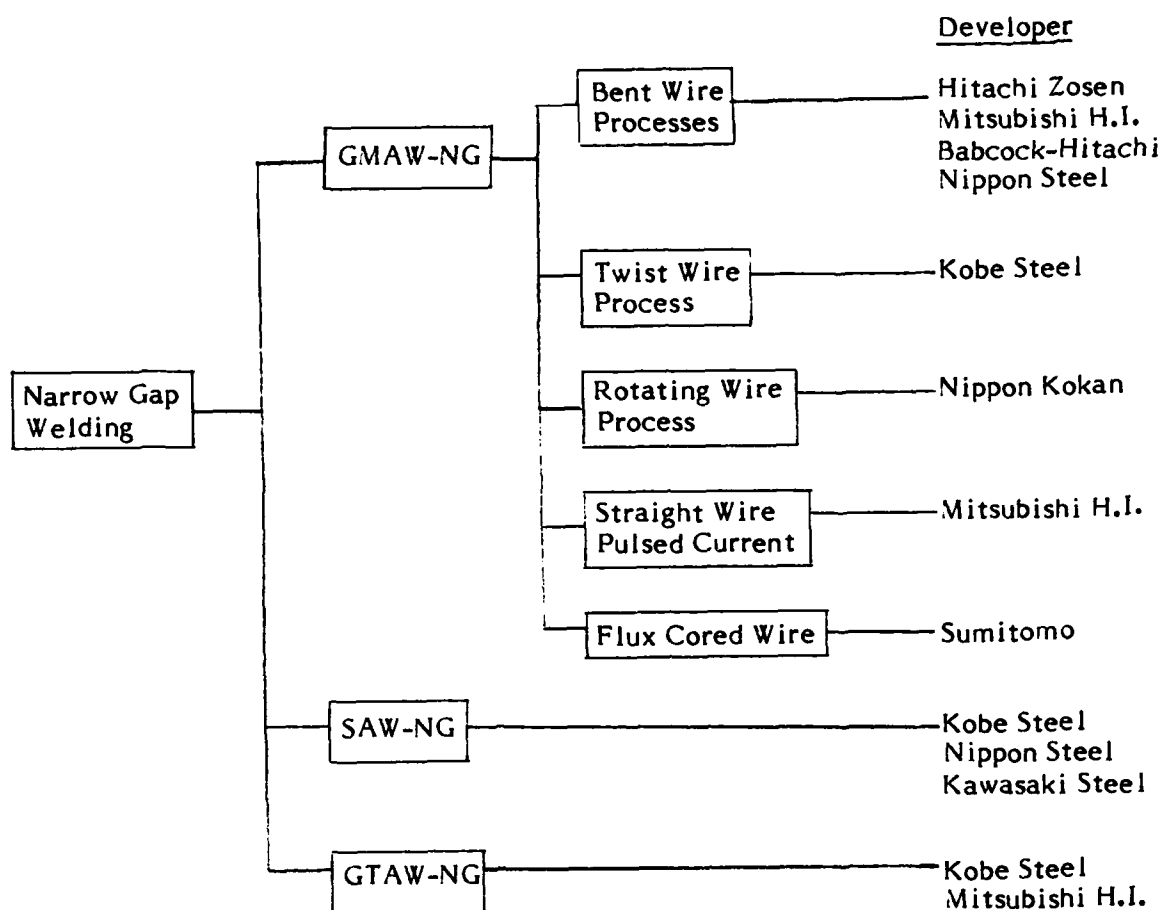
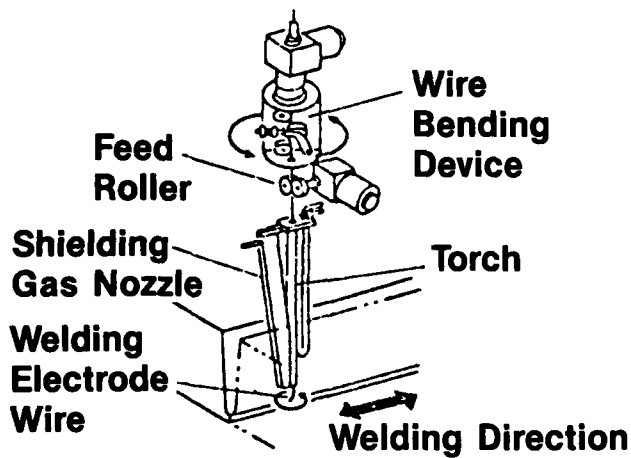


Figure 1. Narrow Gap Welding in Japan



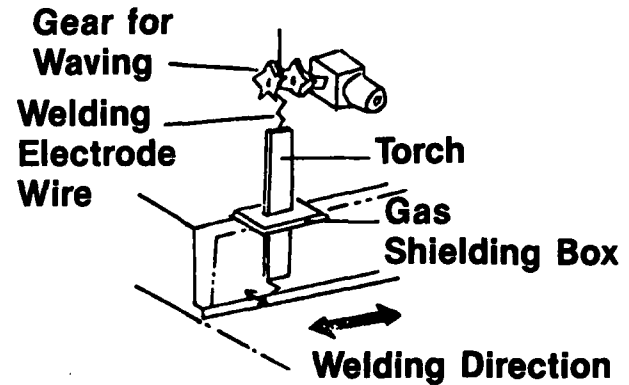
## HITACHI ZOSEN



(Locus of Welding Arc)



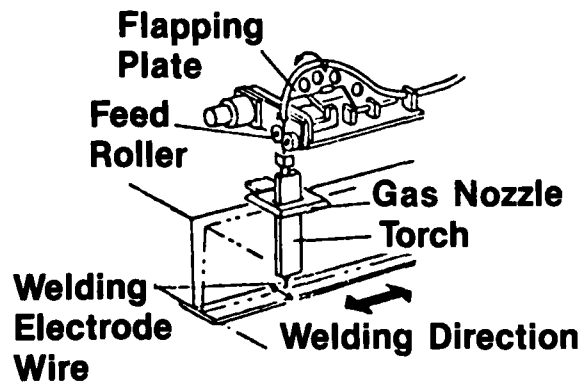
## MITSUBISHI



(Locus of Welding Arc)



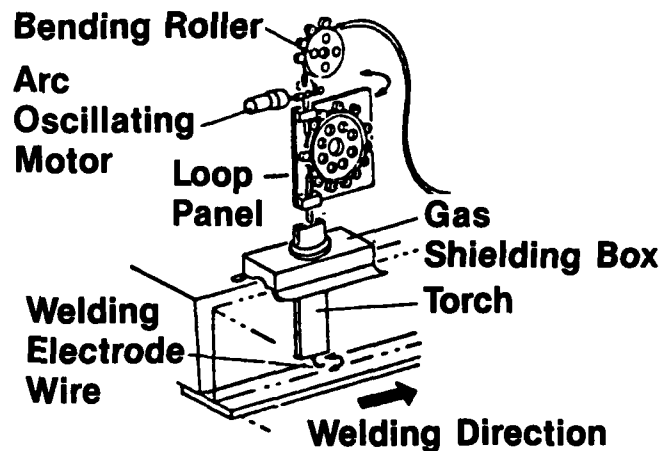
## BABCOCK HITACHI



(Locus of Welding Arc)



## NIPPON STEEL



(Locus of Welding Arc)



Figure 2. Bent Wire Approaches for GMAW-NG. Japan Pressure Vessel Research Council, (1981).

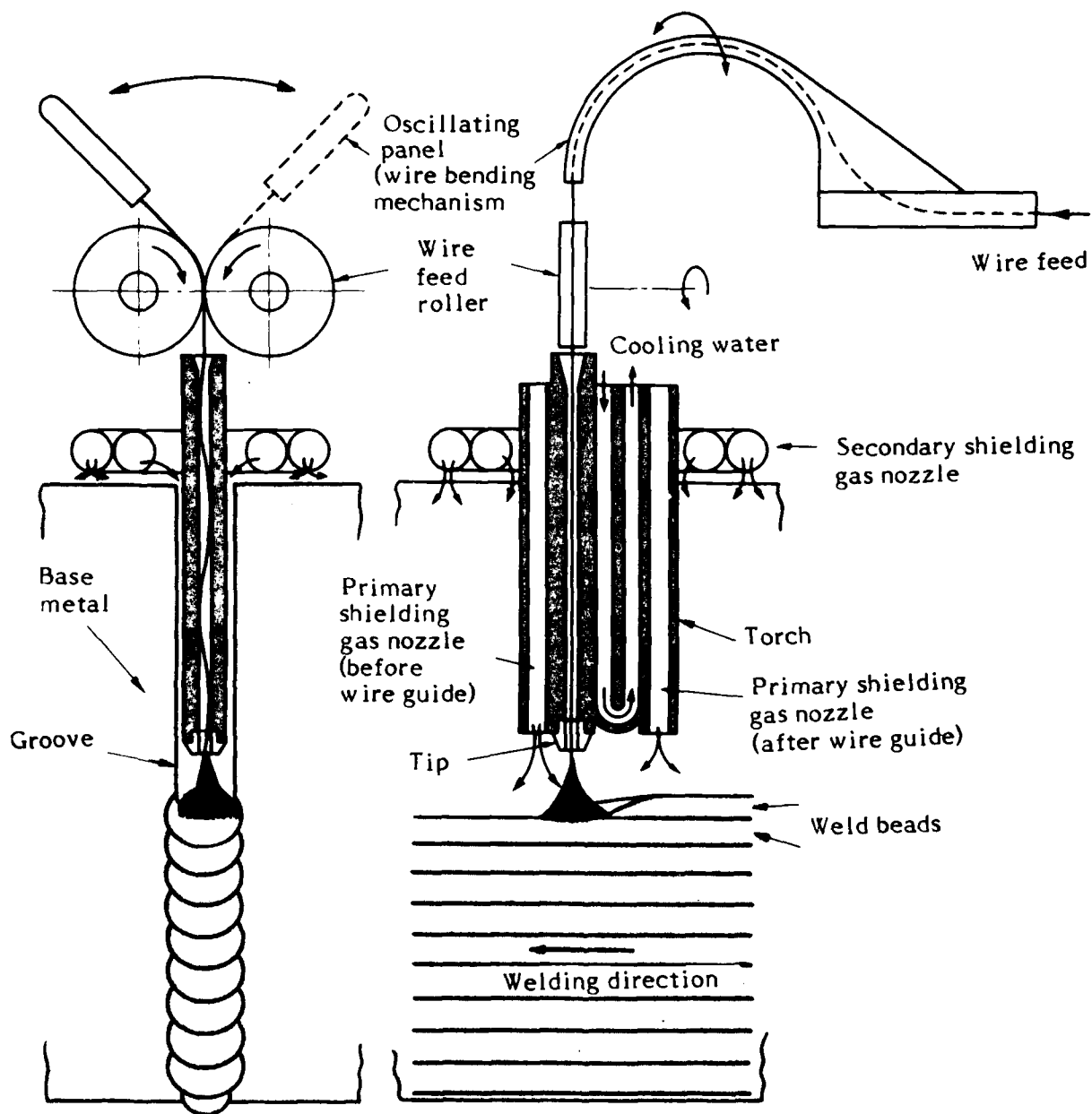


Figure 3. The Babcock-Hitachi Process for GMAW-NG . Hitachi Seiko Catalog (1983).

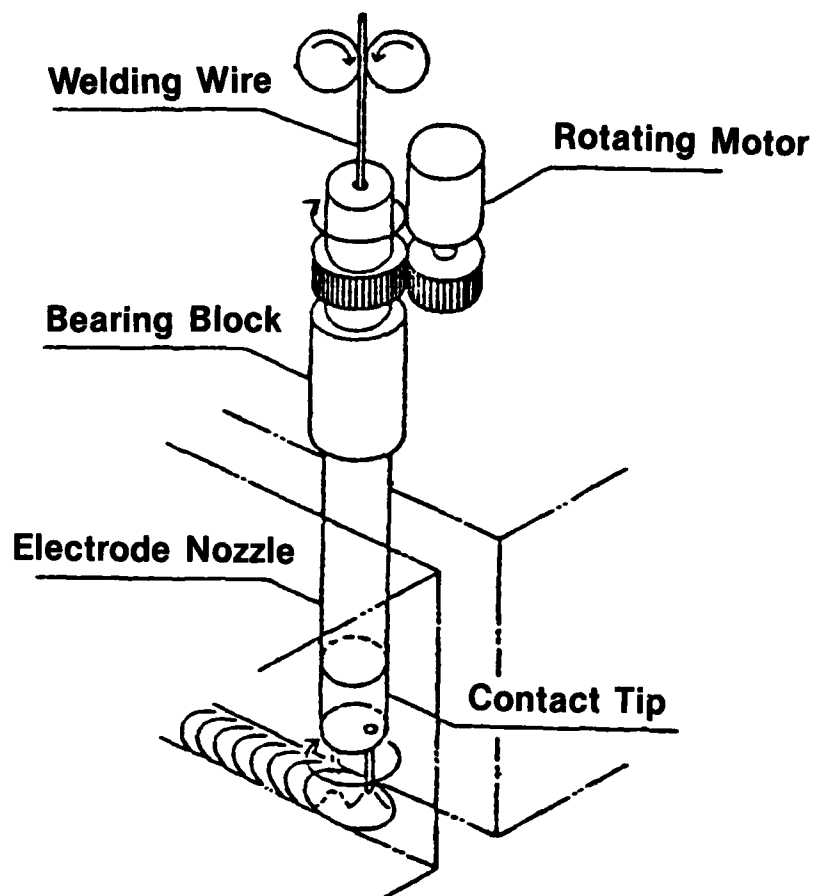


Figure 4. The Rotating Arc Process developed by Nippon Kokan for GMAW-NG. Nomura, H. and Sugitani, Y., IIW Doc. XII-C-083-82, (1982).



Figure 5. Flux Cored Wires for Out-of-position Welding by the GMAW-NG Process. Sumitomo Metal Industries Catalog.

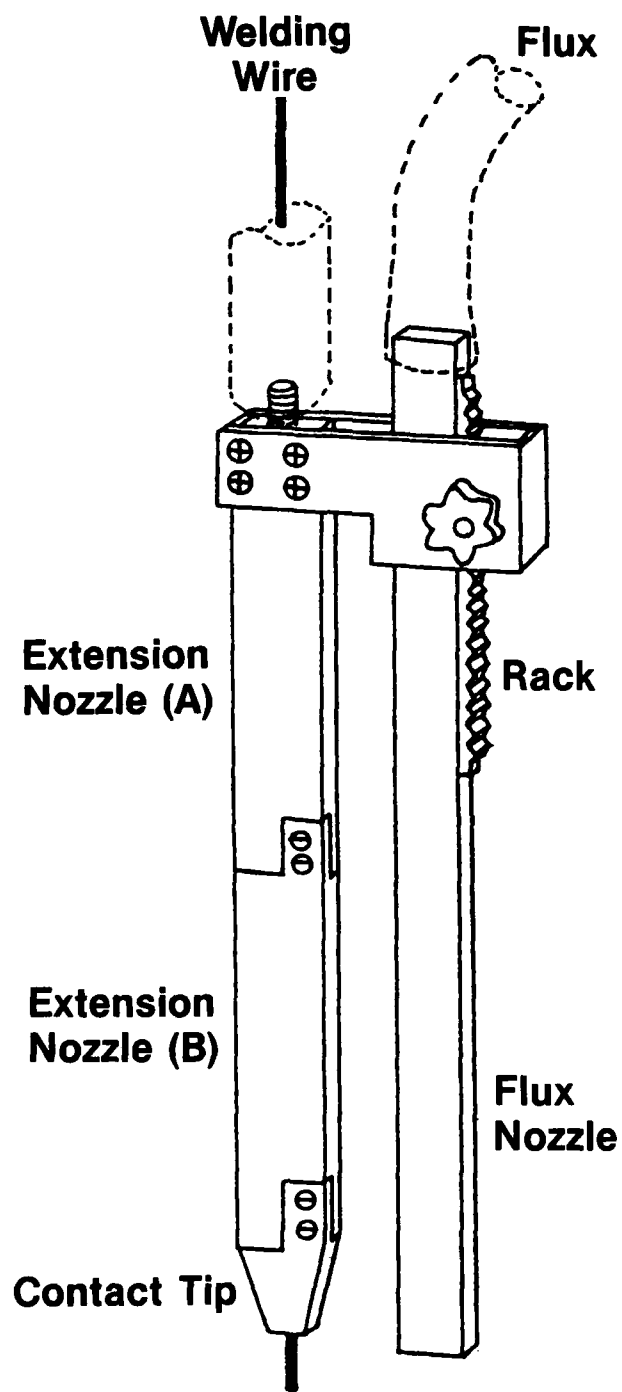
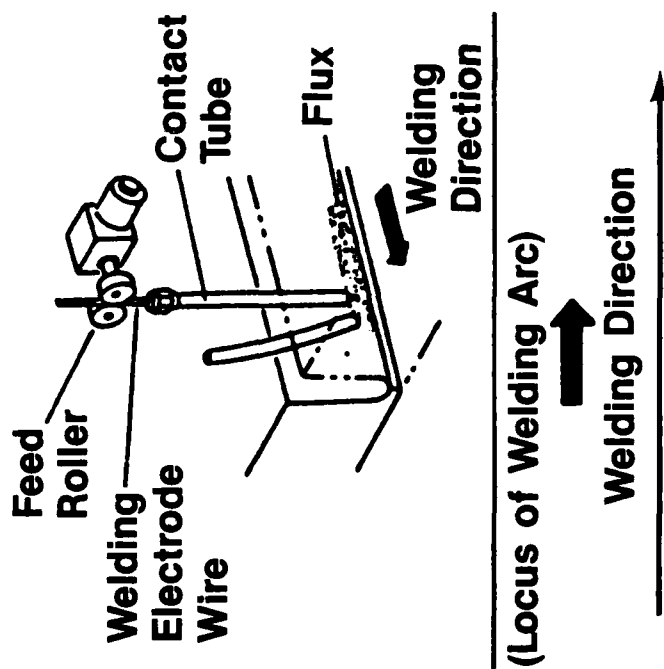


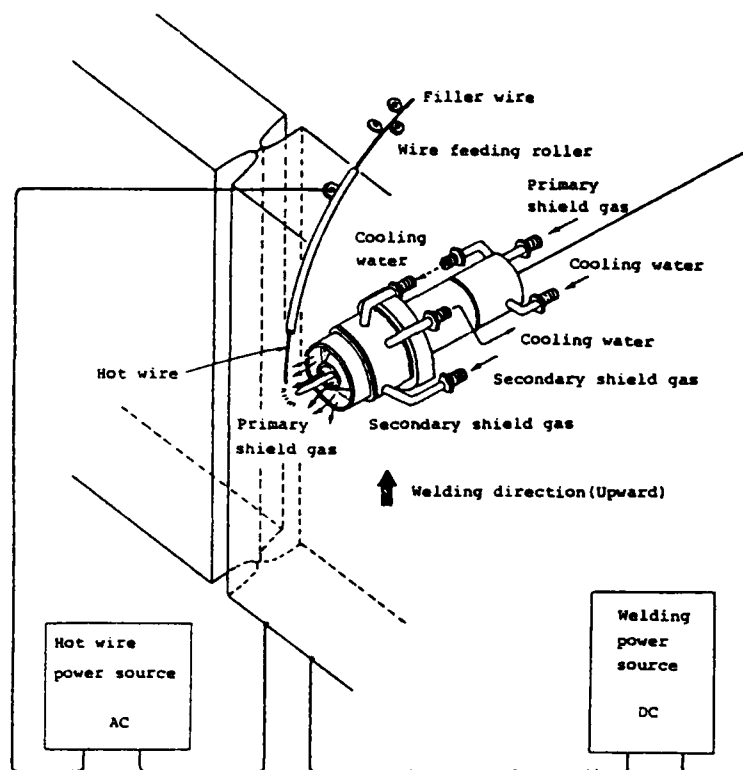
Figure 6. Torch and Nozzle Design for SAW-NG. Hirai, Y. *et al.*, Kawasaki Steel Technical Report, (1982).



## Process Variables (Typical)

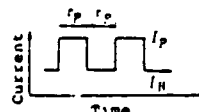
Electrode Diameter, in	.125-.156
Gap (at root), in	0.5
Included Angle	3-7°
Current, A	450-650
Voltage, V	30-35
Travel, in/min	8-14
Heat Input, KJ/in	100

Figure 7. Typical Welding Parameters for SAW-NG. Japan Pressure Vessel Research Council, (1981).



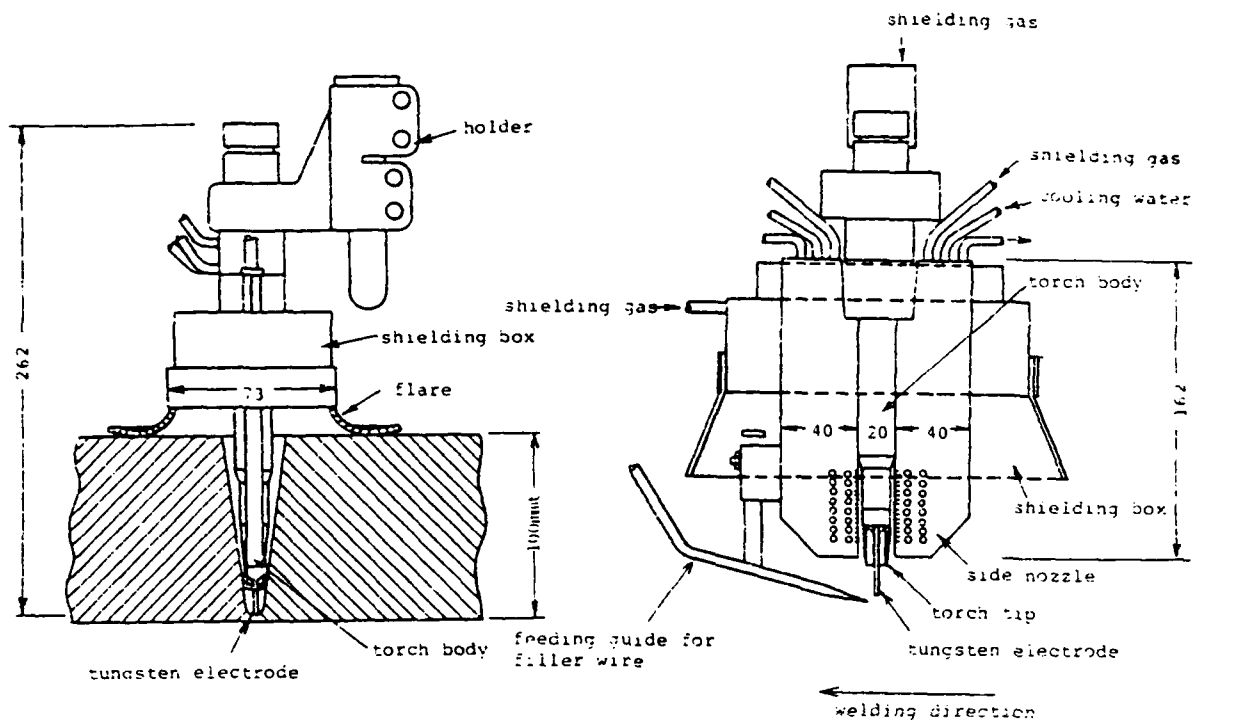
Welding position	Shape of edge	Number of passes	Welding condition								Shield gas
			Welding (1) current		Pulse condition		Welding voltage	Welding speed	Wire heating condition (2)	Wire feeding rate	
			$I_P$ (A)	$I_B$ (A)	$r_P$ (s)	$r_B$ (s)	(V)	(cm/min)	(A × V)	(mm/min)	
Horizontal		1	160	120	0.3	0.5	10	9	—	500	Ar+He
		2	280	200	0.5	0.7	12	13	—	900	
		3	220 380	160 330	0.4 0.6	0.4 0.6	10 12	11 15	90~120 A (2~4 V)	800 1800	
Vertical		1	200	70	0.3	0.3	11	6	—	500	
		2	280	100	0.5	0.6	12	10	—	900	
		3	220 380	160 230	0.4 0.6	0.4 0.6	11 12	8 13	90~120 A (2~4 V)	800 1800	

Note (1)



(2) Heating length: 40~60mm

Figure 8. GTAW-NG Welding of 50 mm thick Stainless Steel in the Vertical and Horizontal Positions. Uratani, *et al.*, IIW Doc. XII-B-039-83.



No. of passes	current (A)	voltage (V)	welding speed (mm/min.)	feeding speed of wire (mm/min.)	Argon gas flow rate (ℓ/min.)			
					torch	side nozzle	rear shielder	back shielding
1	220	12	90	500	15	15	0	30
2	240	12	104	380	15	15	0	30
3	260	12	120	440	15	15	0	30
4 ~ 9	260	12	123 ~ 130	450	15	15	0	30
10 ~ 150	280	12 ~ 13	108 ~ 155	565	15	15	30	0
151 ~ 157	280	12	127 ~ 159	500	15	15	30	0

welding sequence

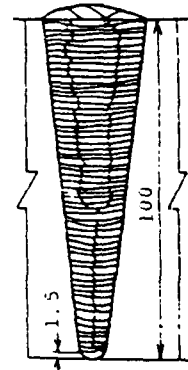


Figure 9. GTAW-NG Selding of 100 mm Thick HT80 High Strength Steel.  
Susei, *et al.*, IIW Doc. XII-B-290-80, 1980.

TABLE I  
TYPICAL PROCESS VARIABLES FOR GMAW-NG WELDING

	<u>Bent Wire</u>	<u>Twist Wire</u>	<u>Straight Wire (MHJ)</u>
Electrode Diameter, in	.045	.078 x .078	.125
Gap, in	.40	.55	.63
Arc Voltage, V	27-32	30	29
Travel Speed, inch/min	7-11	11	6
Heat Input, KJ/inch	50-60	80-90	110
<hr/>			
Shielding Gas	Argon + 20% CO <sub>2</sub>		
Power Source	dc, electrode positive (pulse)		
Welding Position	Flat		
Welding Sequence	1 Pass/Layer		



OCEAN CHARACTERISTICS AND THEIR CHANGES:  
A SPECIAL RESEARCH PROJECT OF THE  
MINISTRY OF EDUCATION, SCIENCE AND CULTURE

Sachio Yamamoto

INTRODUCTION

Over the years the Ministry of Education, Science and Culture (Mombusho) has sponsored a number of special research projects in the ocean sciences. These fall in the Ministry's category of "special project research (tokutei kenkyu)" and about 25 are sponsored at any given time. The ocean science projects have been three-year programs covering a broad area of oceanography. A large number of scientists from nearly all the marine science departments in Japanese universities participate.

DISCUSSION

The most recent project, "Ocean Characteristics and Their Changes" was concluded in April 1984. Its objectives were to study:

- the characteristics of ocean currents and their changes,
- the transport and cycling of seawater constituents,
- the characteristics of the ocean bottom and its changes, and
- to develop oceanographic measurement techniques.

Funding during the three year period was:

JFY 1981 230 million yen (\$1.045 million, \$1 = Y220),  
JFY 1982 250 million yen (\$1.136 million),  
JFY 1983 220 million yen (\$1.0 million).

The overall program is managed by an "umbrella" group headed by Professor Kinjiro Kajiura of the Earthquake Research Institute of Tokyo University. This group is responsible, among other things, for coordinating the research of the various working groups, maintaining communication between the groups, overseeing joint-use of major equipment, and coordinating the operation of research vessels. In addition, they organize symposia and meetings, issue reports, and publish a bimonthly newsletter.

The program is divided into planned and solicited research projects. The former represent approximately 65% of the total effort and consists of 12 projects. The latter are, for the most part, one-year projects which are solicited through requests for proposals. In 1982 there were 12 solicited projects. The 12 planned projects and their project leaders are:

Ocean characteristics in the  
environs of the Kuroshio  
Current

Professor Jiro Fukuoka  
Hokkaido University

Characteristics of ocean  
currents in the continental  
shelf region

Professor Masaaki Aota  
Hokkaido University

Removal processes of chemical substances in the oceans

Professor Shizuo Tsunogai  
Hokkaido University

Elucidation of the environment of the Quaternary Period from ocean sediments

Professor Yokichi Takayanagi  
Tohoku University

Development of acoustic techniques for diagnosing ocean characteristics

Professor Hiroo Yamasaki  
Tokyo University

Effect of bottom topography on the Kuroshio Current

Professor Toshihiko Teramoto  
Ocean Research Institute  
Tokyo University

Study of seawater mixing with chemical tracers

Professor Yoshio Horibe  
Ocean Research Institute  
Tokyo University

Precise study of the ocean bottom in the Japan Trench, Nankai Trough, and Daitoh Ridge

Professor Hideo Kagami  
Ocean Research Institute  
Tokyo University

Development of a simple moored measurement system

Professor Hitoshi Mochizuki  
Electrocommunications University

Distribution and behavior of heavy metals in seawater

Professor Satoru Kanamori  
Water Research Institute  
Nagoya University

Vertical transport of organic substances in seawater

Professor Nobuhiko Handa  
Water Research Institute  
Nagoya University

Mechanism of exchange between nearshore and open ocean waters

Professor Hideaki Kunishi  
Kyoto University

The solicited projects, as stated earlier, are usually one-year efforts and are research which support the planned, three-year program. The following were the solicited research projects in 1982.

Development of basic techniques for monitoring oceanographic parameters

Professor Akira Nakamura  
Osaka University

Analysis of microconstituents in seawater

Professor Tsunenobu Shigematsu  
Kinki University

Microdistribution of mercury, copper, iron, and manganese in nearshore waters

Professor Katsuhiko Matsunaga  
Hokkaido University

Development of a shallow-water,  
electromagnetic current-profiler

Professor Seiichi Kanari  
Hokkaido University

Study of the interactions between  
ocean tides and the Kuroshio  
Current

Professor Kunio Rikiishi  
Hiroshima University

Quasi-two year period  
fluctuations in the Western  
Pacific

Dr. Motoyasu Miyata  
Tokyo University

Analysis of seawater constituents  
with an ion-selective electrode

Dr. Yoshio Umezawa  
Tokyo University

Development of a system for  
handling oceanographic data from  
satellites

Professor Jiro Segawa  
Ocean Research Institute  
Tokyo University

Characteristics of near shore,  
local currents and their changes

Professor Takashige Sugimoto  
Ocean Research Institute  
Tokyo University

Movement of the Nankai Trough:  
analysis of sediments for  
particulates, minerals, and  
fossils

Professor Tsunemasa Shiki  
Kyoto University

Basic studies of ocean current  
measurement methods

Professor Kazuo Kawatate  
Kyushu University

Kuroshio meander viewed as a  
divergence problem

Dr. Akira Masuda  
Kyushu University

#### MARINE CHEMISTRY PROJECTS

Four of the twelve planned projects are chemistry projects. Two were concerned with the transport of chemical substances, one with vertical mixing, and the last with the distribution of trace metals in seawater. These projects will be discussed in some detail below.

##### - Removal Processes of Chemical Substances in the Oceans

The overall purpose of this project was to study the processes by which chemical substances are removed from seawater. Specifically, the objectives were to:

- elucidate the biological and chemical processes by which the solid phase is formed and study their seasonal, geographical, and vertical variations,
- study how particulate matter settles and, in particular, the role of fecal matter and marine snow in the transport process,

- determine the mechanism by which settled matter become resuspended or dissolved.

Under this program, sediment trap experiments were conducted in the eastern Pacific Ocean in the fall of 1982 (Cruise KH-82-5 in Figure 1). The traps were designed by Professor Tsunogai's group at Hokkaido University. In addition to settling matter, water and sediment samples were also collected from the same sites. Settling particulates were analyzed for heavy metals, radionuclides ( $^{234}\text{Th}$ ,  $^{210}\text{Pb}$ ,  $^{210}\text{Po}$ ) and organic substances. The results from these experiments were compared with those made in the North Pacific Ocean in 1978 (Tsunogai *et al.*, 1982) and in the North Atlantic (Brewer *et al.*, 1980).

Among their observations are the following. The total particulate flux was found to vary widely with location. The flux ranged from 67.1 g/m<sup>2</sup>/yr in the North Pacific to 4.8 g/m<sup>2</sup>/yr in the vicinity of Hawaii. On the other hand, the variation in heavy metals and  $^{234}\text{Th}$  in the settling particulates was much smaller and unrelated to the variations in total flux. Concentrations of  $^{210}\text{Pb}$  in the particulates varied according to total flux. In the case of the short-lived  $^{234}\text{Th}$  (24-day half-life), its concentration in settling particles was not very different from that in suspended particulates (which were obtained by filtration). The concentration of Al, a refractory component, increased markedly with depth. There were considerable differences in the compositions of the suspended and settling particulates. Percent organics in the settling matter were higher by factors of 4 to 6, whereas carbonates were lower by as much as an order of magnitude, and Al lower by about a factor of 5. However, the situation for Al is reversed in nearshore waters (Tsunogai *et al.*, 1980). Among heavy metal concentrations in the settling particulates, Cd decreases markedly down to 1000 m and then remains essentially constant, while Mn increases with depth all the way to the bottom.

#### - Vertical Transport of Organic Substances in Seawater

In this project, the transport mechanism of organic matter associated with settling particles was studied. The composition of free fatty acids, triglycerides, fatty alcohols, and hydrocarbons of the materials collected from the sediment trap experiments mentioned above were determined.

Some of their observations to date are:

- Fatty acid and fatty alcohol compositions in the sediment are markedly different from those in settling and suspended matter, indicating that bacterial degradation occurs in the sediment.
- Hydrocarbon composition of the sediment is similar to that in soil, while that in settling particulates have a high contribution of hydrocarbons from phytoplankton.
- Hydrocarbon composition in suspended particulates is very different from that in settling matter. The fraction of short-chain compounds was very low, indicating that the degradation of hydrocarbons is fairly advanced in suspended matter.
- The presence of cyclic hydrocarbons with multiple branch, unsaturated chains in settling particulates indicate that fecal pellets from zooplankton play an important role in the transport of organic matter.

- The flux of organic carbon in the eastern North Pacific was found to decrease to a depth of about 1000 m and then remained relatively constant:

Depth (m)	Flux (mg C/m <sup>2</sup> /d)
740	23.0
940	18.0
1440	6.7
3440	6.6
4240	8.7

#### - Study of Seawater Mixing with Chemical Tracers

The general purpose of this project was to study vertical mixing of seawater and the vertical transport mechanism of chemical elements. Their approach was to use stable isotopes and natural and man-made radionuclides as tracers. The region of interest was the western North Pacific. Data obtained from Cruise KH-82-1 (Figure 1) were combined with those collected over the past ten years from the various cruises of the research vessel *Hakuho Maru* of Tokyo University. The isotopes studies are <sup>3</sup>He, D, <sup>18</sup>O, <sup>3</sup>H, <sup>14</sup>C, <sup>90</sup>Sr, <sup>137</sup>Cs, and nuclides of U, and Th.

One of the results reported by Professor Yoshio Horibe of Tokyo University is a comparison of the vertical distribution of <sup>14</sup>C between 1972 and 1980 (Figure 2). In Figure 2, the concentrations are compared at depths from the surface to 1200 m. There was an increase in <sup>14</sup>C during the intervening seven and one-half years. From these data, a value of  $0.8 \times 10^{-11}$  mol m<sup>-2</sup> yr<sup>-1</sup> was calculated for the atmospheric input of CO<sub>2</sub>.

#### - Distribution and Behavior of Heavy Metals in Seawater

The accurate determination of trace metals in seawater has always been a very difficult task. One of the greatest sources of error is contamination. In this project, a "clean" water sampler was designed and built by Professor Hiroyuki Tsubota of Hiroshima University. This 25-liter sampler (Figure 3) contains a polyethylene bellows which, when triggered by a messenger, expands and draws in water. The water intake arm swings out so that water is collected about a meter away from the hydro wire. All the valves are made of Teflon; the outer shell is made of stainless steel. An all-stainless steel, shipboard clean room was built. It was designed to be a Class 100 room but in actual operation was Class 0. All the shipboard processing of water samples are conducted in this clean room.

The sampler was used on portions of Cruise KH-82-1 and KH-82-5 (Figure 1). The metals studied in this project were Tl, Ag, Pb, Co, Cd, Zn, Ni, Fe, Mn, and Hg. Some of the analytical results obtained by isotope dilution mass spectrometry by Professor Masayo Murozumi of the Muroran Institute of Technology is shown in Table 1. The results for Pb in deep ocean waters compare favorably with those obtained by Professor C. C. Patterson of the California Institute of Technology with water collected with the Caltech sampler.

#### CONCLUSION

Perhaps the greatest benefit of a project such as this is that it provides an excellent mechanism for communication and interaction among the marine scientists of

Japan. A large number of the academic marine scientists participate in these special projects, although many only to a limited extent. The coordination between the working groups, as well as the symposia, and special meetings, bimonthly newsletters, and reports all provide excellent communications.

The next three-year program has been planned but has not, as yet, been approved by the Mombusho. This project is called "Dynamics of Deep Circulation in the Western North Pacific" and, if approved, will start in April 1985.

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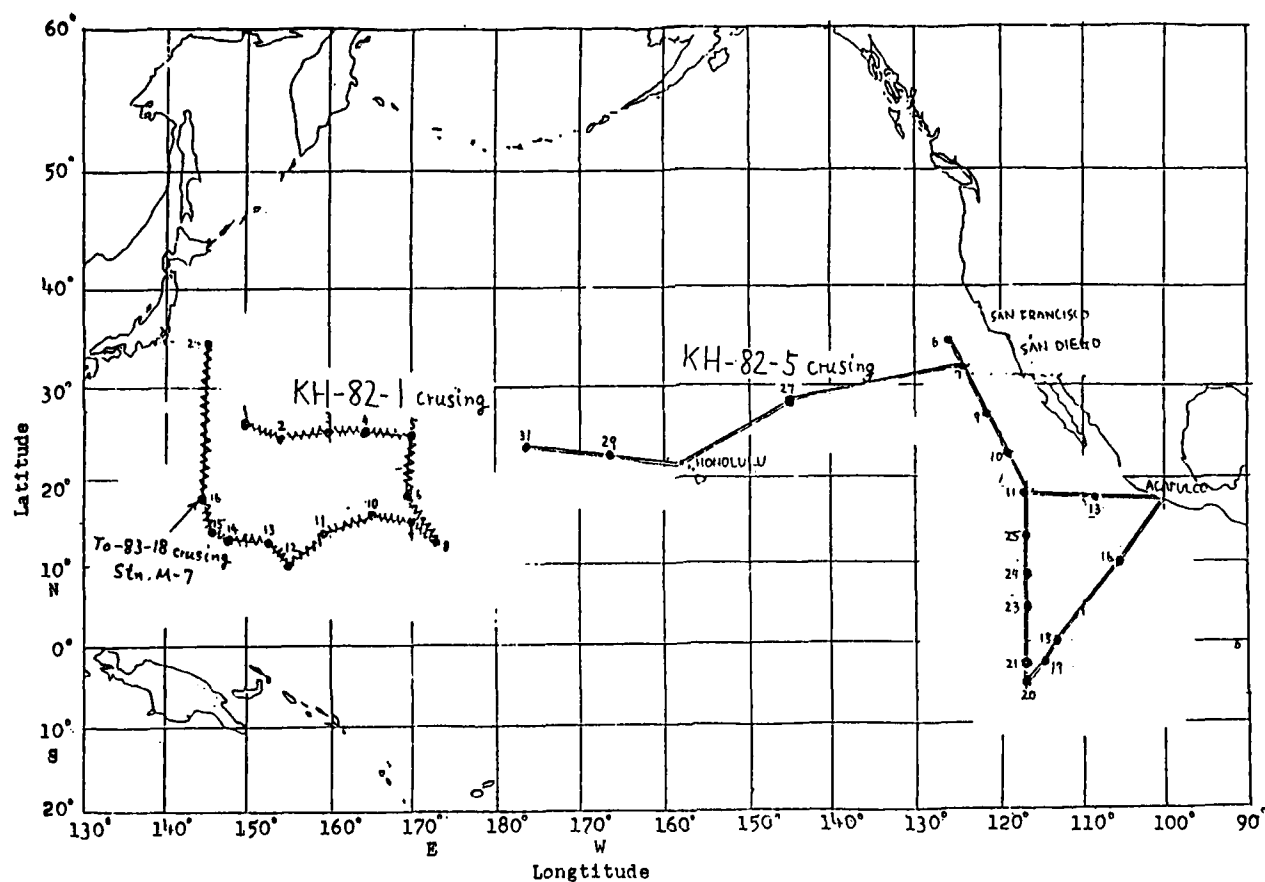


Figure 1. Cruise tracks of the *Hakuho Maru*.

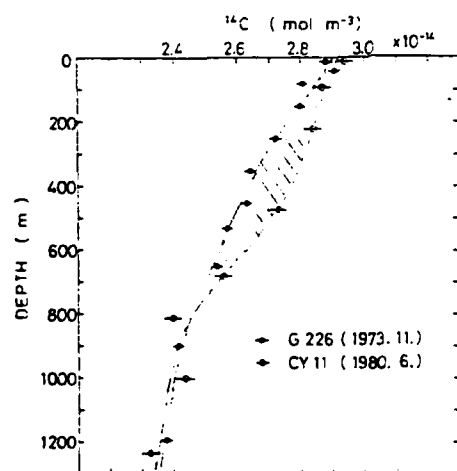


Figure 2. Concentration of  $^{14}\text{C}$  at  $30^\circ\text{N}$ ,  $170^\circ\text{E}$  in 1972 and 1980.

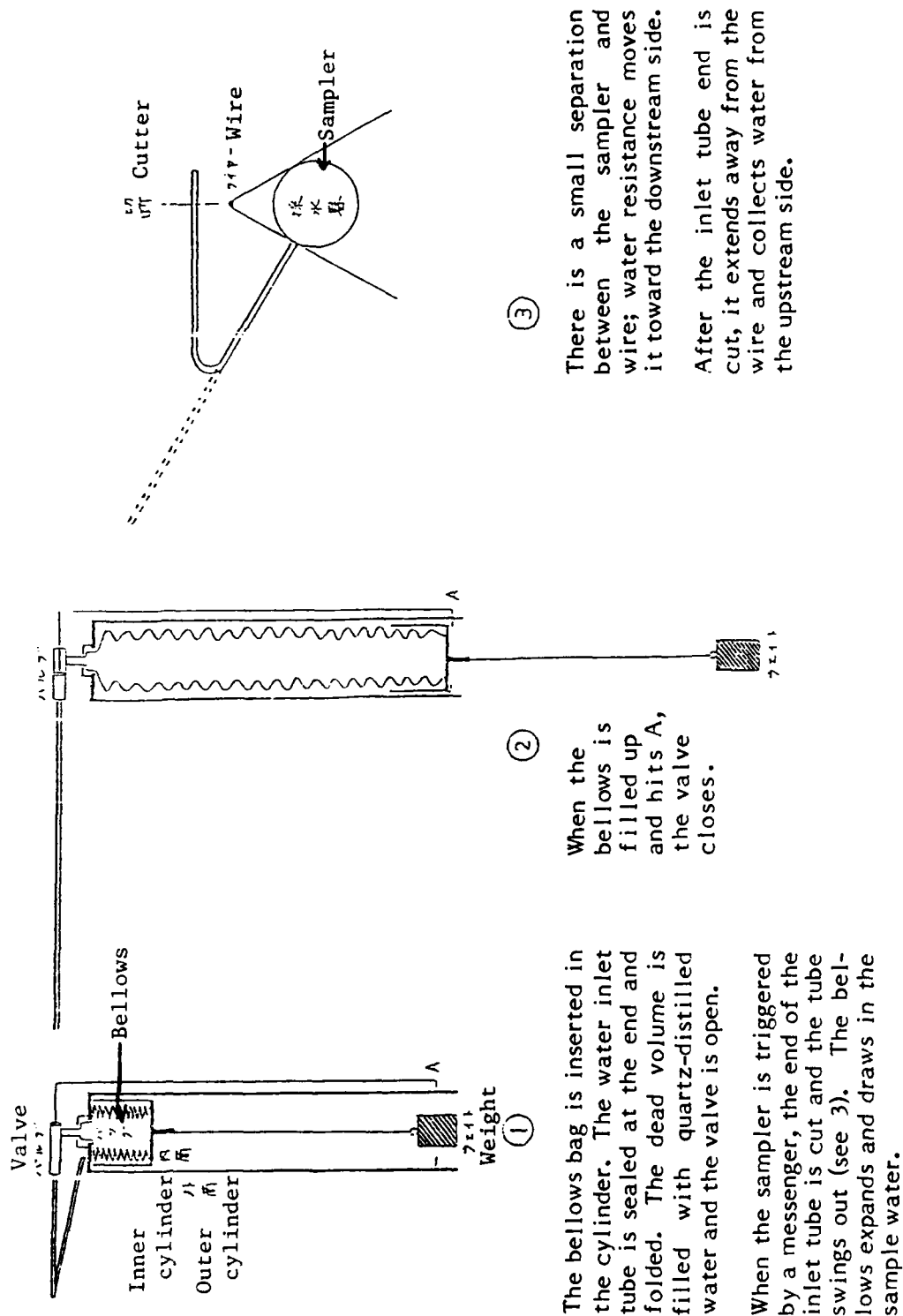


Figure 3. "Clean" water sampler.



TABLE I  
HEAVY METAL CONCENTRATIONS IN THE NORTH PACIFIC  
(CEPHEUS EXPEDITION)

<u>Station</u>	<u>Position</u>	<u>Depth (m)</u>	<u>Tl</u>	<u>Ag</u>	<u>Cu</u>	<u>Cd</u>	<u>Pb</u>
CE- 1	26°01.5'N, 150°00.5'E	0	-	0.41	41.7	0.35	12.8
CE- 2	24°59.6'N, 154°59.6'E	0	14.8	0.20	74.5	0.48	13.0
CE- 5	25°00.2'N, 169°59.3'E	0	14.3	0.19	40.5	5.3	12.8
CE- 6	18°58.8'N, 169°30.4'E	0	13.5	0.14	71	0.31	9.9
CE- 9	15°03.8'N, 169°54.2'E	0	14.4	0.32	200	1.97	15.3
CE- 13	11°58.5'N, 152°30.2'E	0	14.6	0.22	166.9	0.63	12.1
		95	15.2	0.49	43.2	4.73	9.4
		2918	14.0	4.17	212	88.2	3.5
		5385	16.0	3.73	297	83.3	3.7

## BIOLOGICAL MEMBRANE RESEARCH IN JAPAN

P. F. Iampietro

### BACKGROUND

During the past decade there has been a pronounced upsurge in the resources committed to research in the neurosciences in general, and to membrane phenomena specifically. Because of this large increase in activity, a number of federal agencies in the United States formed a loose informal association whose main function was to exchange information in order to maintain an awareness of the research support, progress, and areas of interest of each of the agencies participating. Additionally, the group wanted to be knowledgeable of the research being supported by other than federal agencies in the United States and by other countries since the increased interest was not confined to the United States. Information on the research activities in these areas in the Far East is available primarily through papers published in English language journals and through attendance at international meetings, symposia, and conferences. At best, these sources offer only a restricted and partial picture of the extent of the research being conducted and the published content is already somewhat old, and possibly outdated by the time it appears in print. This report is an attempt to present a synopsis of membrane and related research being conducted at selected institutions in Japan. The institutions (and individuals) visited were those considered to be the most active and progressive. No attempt will be made here to present a critical evaluation of the work reported or to identify individual contributions in each section. A listing of researchers visited, and whose work was included here, is available in the appendix.

### INTRODUCTION

Selective permeability to ions across membranes is the underlying mechanism by which so-called excitable tissues are able to propagate electrical activity. The movement of the ions creates a change in potential difference across the membrane and the propagation of electrical impulses ensues. Membranes have the capability of selective permeabilities to ions because they are composed of lipids, which are practically impermeable to inorganic ions, and proteins which seem to have some very specific ion transport functions. These proteins allow the movement of ions across the membrane when they are in the open position and prevent movement in the closed position. They are therefore referred to as channels. Communication among excitable tissue cells is primarily accomplished by the release of a transmitter (chemical) by one cell at the interface of the two cells (synapse in neurons). The transmitter diffuses across the intracellular space and is recognized and received by receptors on the adjoining cell. This reception sets in motion activity in the adjoining cell. Communication may be among like cells or between neurons and muscle cells or with other types of target cells.

The inorganic ions of greatest interest and importance are  $K^+$ ,  $Na^+$ , and  $Ca^{2+}$ .  $K^+$  is in high concentration inside the cell relative to the outside fluid while  $Na^+$  and  $Ca^{2+}$  are higher in concentration outside the cell. The movement of these ions and others, to a lesser extent, are the subject of many studies.

Some of the areas under study are:

- the permeability to ions,
- transmitter release and/or reception,

- chemical composition of cell and external fluid,
- enhancer and inhibitor concentrations and effects,
- channel kinetics, and other functions and entities.

Experimental material varies widely and includes *Chara* cells and other plants, tunicate eggs, squid giant axons, mammalian brain slices, mollusc neuromuscular tissues, cultured human cells and many others.

#### - Development of Excitable Membranes and Coupling

A number of workers have shown that in many animal species, influx of cations through  $\text{Na}^+$  and/or  $\text{Ca}^{2+}$  channels influences some early events in embryonic development. Differentiation of excitable membranes of the egg may be dependent on ion channel activity. Both passive and active electrical phenomena have been studied in several species. In the ascidian (tunicate) the early stages after fertilization (up to gastrula stage)  $\text{Na}^+$  and  $\text{Ca}^{2+}$  currents were reduced, but in later stages both currents were enhanced. When enhancement occurs, differentiation of excitable cells also occurs.  $\text{Na}^+$  channels remain only in presumptive neural blastomeres after differentiation while  $\text{Ca}^{2+}$  channels are in most blastomeres.  $\text{Ca}^{2+}$  channels exist in oocytes of many animal species and any excitable membrane has a component of a  $\text{Ca}^{2+}$  current with membrane depolarization. When tunicate eggs are pathogenetically activated, large changes occur in currents which already exist in the unfertilized egg membrane.  $\text{Ca}^{2+}$  channels decrease at the same time as  $\text{Na}^+$  channel current increases. This is a somewhat different sequence than during normal fertilization. The same changes can be evoked by intracellular perfusion of high  $\text{Ca}^{2+}$  (above  $10^{-8}$  M) concentration.

Epidermal cells of the newt (*Cynops pyrrhogaster*) embryo exhibit action potentials at stage 31 which consist of a fast spike followed by a slow component. The slow component can evoke action potentials in adjacent cells and induces transmission to other cells. Fast spikes appear in all epidermal cells (stages 26-47). Slow potentials appear at stage 28, persist until stage 36-37 and disappear at stage 38-42 (after hatching). Speculation is that there is a transient establishment of excitable new membranes in epidermal cells during differentiation which is closely related to neural cell differentiation. The slow action potential is transmitted to other cells via ionic channels. Transmission seems to be  $\text{Na}^+$  dependent (it does not occur in  $\text{Na}^+$  free solutions or after TTX (tetrodotoxin) treatment. Fast action potentials are blocked by  $\text{Co}^{2+}$  and appear to be  $\text{Ca}^{2+}$  dependent. The slow potential is transmitted chemically (can be transmitted even to electrically uncoupled cells). Acetylcholine (ACh) may mediate the slow potential. Cultured explants show essentially the same action potentials as *in vivo* preparations.

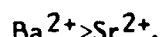
Electrical and chemical coupling of cells are important aspects of the functional ability of the cells in the transmission of information. Mouse macrophages, cultured *in vitro* couple to each other electrically. When external  $\text{Ca}^{2+}$  was increased, there was an increased occurrence of coupled cells. Verapamil prevented the  $\text{Ca}^{2+}$  effect, while increasing the concentration of  $\text{Mg}^{2+}$  had no effect. The  $\text{Ca}^{2+}$  ion may act on the cell surface in some manner to facilitate coupling. In human FL cells in culture, TPA (a tumor promoter) prevented electrical coupling and other tumor promoters also inhibited coupling. Electrical properties of the cell membrane were not changed by these chemicals. It is thought that electrical coupling is prevented without changing the properties of the membrane. Aminophylline plus AMP prevented the TPA-induced inhibition in electrical coupling, if the compounds were added at the same time as TPA, but could not reverse the effects of TPA once the TPA effect was established. So AMP

can only counter the early membrane effects of TPA. The TPA effect is reversible (by other means). TPA can decouple already coupled cells as well as prevent coupling. TPA acts on intercellular communication (electrical coupling) mediated by specific binding (reversible) to cellular receptors.

#### - Ionic Channels

The movement of ions across membranes and the resulting propagation of electrical activity occurs through channels as described earlier. A number of Japanese workers are concerned with elucidating the characteristics and functions of ion channels.

In the rat clonal pituitary cells, the  $\text{Ca}^{2+}$  channel enters the activated state with voltage dependent and relatively slow kinetics. The channel then flickers between open and closed states at a substantially faster rate which is relatively voltage independent. In these same cells, using a patch electrode voltage clamp technique, it was found that the amplitude of  $\text{Ba}^{2+}$  current increased linearly with increasing concentration up to 25 mM. There was a positive shift of the current voltage along the voltage axis with increasing  $\text{Ba}^{2+}$  concentration possibly due to a screening effect of  $\text{Ba}^{2+}$  on negative surface charges. In the tunicate, *Halocynthia roretzi*, the potency of current inactivation was determined for several ions as follows:



$\text{K}^+$  caused greater inactivation when in combination with  $\text{Na}^+$ . One  $\text{K}^+$  was found to inactivate a channel cooperatively with one  $\text{Na}^+$ . Plugging occurred when a monovalent inactivator combined with  $\text{K}^+$ .

The outward  $\text{K}^+$  current in isolated vestibular hair cells of the chick is carried mostly through  $\text{Ca}^{2+}$  activated  $\text{K}^+$  channels.  $\text{Ca}^{2+}$ ,  $\text{Sn}^{2+}$ , and  $\text{Ba}^{2+}$  solutions caused decay of the inward current. When quinine (100  $\mu\text{M}$ ) was added to the medium, the decay of inward current was eliminated probably due to the activation of some  $\text{Ca}^{2+}$  activated  $\text{K}^+$  conductance which remained even with isotonic  $\text{C}_5\text{Cl}$  and EGTA in the internal medium.

In the squid giant axon, an outward osmotic gradient (provided by nonelectrolytes) had effects specifically on the  $\text{K}^+$  channel. It appears the outflow of fluid washes  $\text{K}^+$  ions away from the outside mouth of the channel and suppresses the inward flow of ions.  $\text{K}^+$  ions accumulate at the inside mouth of the channel which makes the channel more sensitive to  $\text{K}^+$  ions in the external solution. An important consideration is that water flow does not occur through  $\text{Na}^+$  channels.

When viscosity inside or outside the giant axon was increased with nonelectrolytes, the time course of excitation was slowed without changing the resting potential or amplitude of the action potential. A twofold increase in viscosity caused a 2.7-fold increase in duration of the action potential. The time course of inward and outward current was also slowed. Permeable nonelectrolytes on one side of the membrane and impermeable nonelectrolytes on the other side caused smaller membrane currents flowing from the impermeable to the permeable than the other way.

Cationized ferritin (CF) (positive multivalent charge) binds to the membrane's inner surface (axolemma) and induces a prolonged action potential caused by a prolongation of inward current primarily due to the suppression of the inactivation of the  $\text{Na}^+$  channel and  $\text{K}^+$  channel activation. CF binds to anionic sites near ionic channels.

Intracellular divalent ions ( $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{Sr}^{2+}$ ,  $\text{Cp}^{2+}$ ,  $\text{Mn}^{2+}$ ,  $\text{Ni}^{2+}$ ,  $\text{Ba}^{2+}$ ,  $\text{Zn}^{2+}$ ) with giant axon have various effects on  $\text{Na}^+$  and  $\text{K}^+$  channel permeabilities.  $\text{Sr}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{Mn}^{2+}$ ,  $\text{Co}^{2+}$  suppressed the inward current ( $\text{Na}^+$  channel) and outward current ( $\text{K}^+$  channel) while  $\text{Be}^{2+}$  and  $\text{Cd}^{2+}$  had no effect.  $\text{Ni}^{2+}$ ,  $\text{Ba}^{2+}$ ,  $\text{Zn}^{2+}$  suppressed the inward current. Internally perused  $\text{Ca}^{2+}$  in the giant axon, after removal of axoplasm, caused an unstabilized membrane and opened the excitation channel ( $\text{Na}^+$ ). External  $\text{Ca}^{2+}$  caused the opposite effect.

When giant axons are placed in glycerol plus an electrolyte solution, they can be excited even at temperatures as low as  $-19^\circ\text{C}$ . Excitation is very slow and time constants are larger than normal. The membrane was not disrupted by severe cooling.

Interesting work has been done with the mollusc (*Onchidium verruculatum*) identified neuron Be-1 which has an intrinsic beating activity. When  $\text{Na}^+$  or  $\text{Ca}^+$  is removed from the bathing solution, a partial reduction in the somatic potential occurs. Removing both ions abolishes the spike. In  $\text{Ca}^{2+}$  free solution the somatic spike overshoots and varies with  $\text{Na}^+$ . The  $\text{Na}^+$  dependent component of the somatic spike is blocked by tetrodotoxin (TTX). The  $\text{Ca}^{2+}$  dependent component is blocked by  $\text{Co}^{2+}$  or  $\text{Mg}^{2+}$  ions. The axonal action potential disappears in  $\text{Na}^+$  free or TTX solutions, but is not affected by  $\text{Co}^{2+}$  or removing  $\text{Ca}^{2+}$ .

In *Nitellopsis obtusa*,  $\text{Ca}^{2+}$  in low concentrations with ATP present, had no effect on membrane potential or resistance, but at high  $\text{Ca}^{2+}$  concentrations the membrane was depolarized and resistance decreased almost to zero. If the electrogenic pump was stopped (by removing ATP), the effect of  $\text{Ca}^{2+}$  was about the same indicating that the pump was not required for the effect.

The  $\text{K}^+$  channel activation in *Nitella axilliformis* is responsible for the after hyperpolarization (AH) effect. The evidence is that AH is inhibited by extracellular  $\text{K}^+$  and  $\text{Rb}^+$ , but not  $\text{Na}^+$  and  $\text{Li}^+$ . Also AH was not inhibited by intracellular tetraethylammonium ( $\text{TEA}^+$ ) but was by extracellular  $\text{TEA}^+$ . The  $\text{K}^+$  channel activation was also involved in the repolarizing process of the action potential as indicated by the fact that extra and intracellular  $\text{TEA}^+$  and extracellular  $\text{Co}^{2+}$  prolonged the action potential.  $\text{Ca}^{2+}$  may be involved in the  $\text{K}^+$  channel activation.

#### - Some Metabolic Aspects of Excitable Cells

Energy requiring activities of excitable tissues have been studied extensively, notably in algae. The *Chara australis* cells are made tonoplast-free by perfusing with the  $\text{Ca}^{2+}$  chelator EGTA. When internal ATP was present, the efflux of  $\text{H}^+$  was high. The ATP dependent  $\text{H}^+$  efflux was about 40 m moles/ $\text{m}^2$ /sec. The activity of the pH pump in *Chara* can be controlled by regulating the internal ATP or  $\text{Mg}^{2+}$  concentration. In cells with  $\text{Mg}^{2+}$  and ATP, the membrane potential and membrane resistance were very sensitive to pHo. Membrane potential was more negative in the light than in the dark at all pHo values. Cells with low  $\text{Mg}^{2+}$  or ATP showed very weak dependence of membrane potential and membrane resistance on pHo. The active component of membrane potential was sensitive to pHo.

In tonoplast-free *Nitella axilliformis*, if ADP and ATP were in the perfusion solution, the membrane hyperpolarized in the dark similar to light-induced hyperpolarization. This effect might be due to activation in the electrogenic ion pump in the plasma membrane. Hyperpolarization was inhibited by the respiratory inhibitors NaCN and rotenone.

In the newt, the membrane potential of mucous epithelial cells of the stomach decreased to -23 mV at 7°C; also when the external solution was K<sup>+</sup> free or ouabain or DNP were applied. These data show that even at low temperature and other treatments, active ion transport mechanisms are still capable of function. Zn<sup>2+</sup>, Cu<sup>2+</sup>, Cd<sup>2+</sup> lowered the membrane potential without changing the effective membrane resistance and electrical coupling ratio. Ions may inhibit active transport by combining with SH groups of cell membrane thereby lowering the membrane potential.

#### - Neurotransmitters and Receptors

The transmission of signals across junctions, neuron to neuron, neuron to muscle fiber or between any two excitable cells is accomplished through the release at one terminal and reception at the other terminal of chemical substances transmitters. Elucidation of the process(es) of release, transmission and reception, and factors which modify them will be considered here.

In the mammalian central nervous system, ATP is stored along with the neurotransmitter (acetylcholine or catecholamines) in the synaptic vesicles and released under the appropriate stimulation--the arrival of an electrical signal at the terminal.

After tetanic stimulation, ATP and neurotransmitters are released into the synapse, ATP breaks up into ADP and AMP which is further broken into adenosine and components. Adenosine inhibits further release of the neurotransmitter. Concurrently, adenosine causes an increase in cyclic AMP in stimulated nerve terminals. As adenosine disappears post-tetanic potentiation is observed until cyclic AMP reaches normal levels. Adenosine can also diffuse to adjacent fibers and have its effect there. In guinea pig papillary muscle, the slow inward current can be suppressed by Co<sup>2+</sup>. Atropine restores the slow inward current. ACh inhibits the Ca<sup>2+</sup> current and is augmented by catecholamines. ACh may decrease tension development in the muscle by depressing the slow inward current thereby preserving the duration of the action potential.

There are neurotransmitters for each of several types of postganglionic potentials and also specific antagonists. Fast excitatory postsynaptic potentials (f-EPSP) are elicited by nicotinically-acting ACh while slow inhibitory and slow excitatory postsynaptic potentials (s-IPSP and s-EPSP) are elicited by muscarinically acting ACh. Adrenergic cells release dopamine which in turn hyperpolarize the ganglion cell. The transmitter for the late s-EPSP may be a luteinizing hormone releasing factor--like peptide. Mammalian cells are depolarized by substance P. Atropine antagonizes ACh activity on adrenergic cells while dopamine is antagonized by an alpha blocker. Atropine also blocks the ACh effect on EPSP and curare antagonizes the ACh effect on EPSP. Except for the atropine effect on adrenergic cells, all other effects occur in the ganglion cell. Cyclic AMP mediates the dopamine effect on s-IPSP while cyclic GMP mediates the effect on s-EPSP. Cyclic GMP can disrupt the cyclic AMP dopamine effect on s-EPSP. Cyclic AMP may start a reaction which facilitates transmission of the signal. It may also increase the number of receptors. Short-term memory may be related to the chemical effect of cyclic AMP, while long-term memory may be a function of neurotransmitter changes in plasticity.

In experiments with guinea pig brain slices, drugs or chemicals can be selectively injected through a multibarrelled electrode thereby activating synapses near the tip of the electrode. When the slices were in solutions with low Ca<sup>2+</sup> and high Mg<sup>2+</sup> and concentrated CaCl<sub>2</sub> was injected, those fibers having presynaptic terminals in the area near the electrode release large amounts of transmitters and induce large EPSP's in

postsynaptic neurons. Antagonists of excitatory amino acids blocked excitation induced in mossy fiber neurons by glutamate. A specific blocker of synaptic transmissions between mossy fibers and CA3 neurons, is 2-amino-4-phosphonobutyric acid (APB), and this effect is not the result of blockade of receptors for glutamate or aspartate. There was no change in resting potential, action potential, or membrane conductance. D- and D, L-homocysteate induced large depolarizations in CA3 neurons. Receptors for homocysteate in the hippocampus have different properties than in the spinal cord and are quite similar to glutamate receptors. Receptor activity was essentially negative in response to D-glutamate and N-methyl-D-aspartate.

In the frog taste organ, evidence has accumulated that noradrenaline is a likely transmitter from taste cells to the sensory nerve. These workers perfused noradrenaline, dopamine, and adrenaline and all produced an increase in spontaneous glossopharyngeal nerve discharges as well as enhancement of taste responses to various chemical stimuli. Noradrenaline was the most effective. Monoamine-releasing agents such as tyramine, enhanced spontaneous nerve discharges but depressed taste responses. Alpha blockers increased nerve discharges. Serotonin is not a chemical mediator in the frog taste organ. Serotonin antagonists did not change the response to serotonin.

In the mollusc (*Onchidium verruculatum*), histamine inhibited the activity of neuron Be-1. Cyclic AMP enhanced both amplitude and duration of the inhibitory histamine response and cyclic GMP depressed the histamine response. There are histamine sensitive areas (receptors?) along the axon of the neuron and specific blockers could be used against those receptors. Histamine caused no change in membrane conductance and removal of  $\text{Na}^+$  and addition of ouabain blocked the response.

The clam (*Mytilus*) retractor smooth muscle responds to catecholamine-related compounds. The effect is on the relaxing nerve endings causing an increase in the neurotransmitter serotonin in the junctional clefts.  $\text{Zn}^{2+}$  acts on the muscle membrane and at nerve terminals, both cholinergic and serotonergic.  $\text{Zn}^{2+}$  increases  $\text{Ca}^{2+}$  stores.

In body wall strips of the marine worm (*Urechis unicinctus*) amino acids caused contractions (L-proline was most effective). Cholinergic agents caused direct action on muscle fibers. Amino acids act on the epidermal chemoreceptor organs. ACh may be the excitatory transmitter at the neuromuscular junctions in the body wall.

Retinal explant cultures have enhanced neurite outgrowth when chick gizzard extract is used and have greatly increased uptakes of aspartate and glutamate. These are thought to be neurotransmitters.

Membrane excitability of hybrid and muscle cultured cells is influenced by prostaglandins. Ionic channels activity (membrane excitability) was followed by neurotransmitter secretion and an adenylate cyclase.  $\text{TXB}_2$  (thromboxane) had no effect, which means the cells had no receptors for  $\text{TXB}_2$ . Prostaglandins elicited prolonged depolarization in hybrid cells and increased miniature end plate potential frequency. Since prostaglandin-2 is prevalent in the brain it could have an important neuron modulating role.

#### - Toxins and the Effects on Channels and Transmitters

Various chemicals, venoms, toxins and other entities have been used to help in explaining the mechanism by which excitable tissues function. Toxins have been most frequently used.

A toxin from Joro spiders (JSTX) selectively inhibits EPSPs without altering IPSPs in the lobster walking leg while the resting membrane potential was not changed. JSTX seems to block depolarization of the postsynaptic membrane which was induced by L-glutamate. In contrast, L-aspartate-induced depolarizations were not affected. JSTX also suppressed evoked EPSPs in muscle fibers. The potentiating effect on glutamate-induced depolarizations was also suppressed. JSTX probably blocks glutamate receptors whether they are junctional or nonjunctional. The effects are not reversible. JSTX blocks glutaminergic transmission in the CNS as well as in crustacean neuromuscular junctions. The toxin acts on postsynaptic membranes reducing the sensitivity to transmitters. Squid giant synapse glutamate receptors were also blocked. EPSP was irreversibly blocked while presynaptic potential and antidromic action potentials were not affected. Normally, L-glutamate depolarizes postsynaptic membranes and suppresses EPSP. So, glutamate may be a neurotransmitter of squid giant synapse.

In the spiny lobster, the presynaptic action potential failed to propagate when TTX (tetrodotoxin) was added to the medium and  $\text{Na}^+$  was removed. If 4-aminopyridine was added to a  $\text{Na}^+$  free solution containing TTX, synaptic transmission was restored. The action potential of the presynaptic axon of the lobster neuromuscular junction depends on both  $\text{Na}^+$  and  $\text{Ca}^{2+}$ . Chemotransmission leads to generation of  $\text{Na}^+$  spikes in the conductile part of the axon and the ensuing depolarization of the nerve terminals which is associated with an increase in  $\text{Ca}^{2+}$  conductance and to transmitter release.

Tetanus toxin (TNTX) blocks the slow action potential in cultured mouse neuroblastoma cells which is elicited in a  $\text{Na}^+$  free medium and whose amplitude depends on an extracellular concentration of  $\text{Ca}^{2+}$ . The resting membrane potential was not changed. Inhibition of  $\text{Ca}^{2+}$  dependent spikes was mimicked by  $\text{CoCl}_2$  and  $\text{MnCl}_2$  but not by boiled or neutralized TNTX. It appears that TNTX inhibits electrogenesis of  $\text{Ca}^{2+}$ , but not the  $\text{Na}^+$  components of action potentials of neuroblastoma cells.

In the isolated guinea pig superior cervical ganglia presynaptic nerve terminals, methyl mercuric chloride caused the release of large amounts of transmitter (*in vitro*). Mercuric chloride acts on both presynaptic (releases small amounts of neurotransmitter) and postsynaptic (sustained depolarization) nerve terminals.

In the frog sciatic nerve-sartorius muscle preparation, methyl mercuric chloride and mercuric chloride acted at the same sites as in the guinea pig preparation. In addition, mercuric chloride decreased the resting potential, effective resistance, amplitude of the potential, and led to electrical inexcitability in the frog preparation.

The leaves of the plant family *Eucacea* (rhododendron) contain a material which has been named grayanotoxin (GTX) and which has profound effects on membrane phenomena. The biological activity of GTX depends both on stereospecificity and hydrophobicity of the molecules. Essential groups are hydroxyl and methyl. The effects of GTX have been studied in the rabbit sino-atrial nodal membrane.  $\text{Na}^+$  permeability in this membrane is high. GTX causes membrane permeability to  $\text{Na}^+$  to increase causing a large depolarization. The effects of GTX were antagonized by tetrodotoxin (TTX). GTX causes the  $\text{Na}^+$  channel to open with a very slow time course. The effects of GTX appear to be directly on the channel.

In other work with the frog neuromuscular junction, GTX caused the depolarization of both end plate and the non-end plate region of the muscle fiber. GTX depletes synaptic vesicles, but does not alter the sensitivity of the end plate membrane to ACh.



Removal of  $\text{Ca}^{2+}$  prevents GTX from depleting the vesicles and TTX (or removal of  $\text{Na}^+$ ) prevented GTX from inducing depolarization and increasing membrane end plate potential frequency. Possibly, the GTX action is due to an increase in permeability to  $\text{Na}^+$  leading to depolarization of both pre and postsynaptic membranes.

The use of poisons has given valuable information on the existence of membrane pumps in fresh water algae. It is postulated that an electrogenic pump, as well as a passive pump, exist in *Chara* and *Nitella* plasma membranes based on:

- the membrane potential is more negative than calculated by the Nernst potential across the plasmalemma for each of the ions  $\text{K}^+$ ,  $\text{Na}^+$ ,  $\text{Cl}^-$ ,  $\text{OH}^-$ ,
- membrane potential is sensitive to light, temperature, and metabolic poisoning.

After poisoning, *Chara* in the dark, ATP showed no change, then decreased to less than one-half in four days. The final level after poisoning was 50% in light and less than 40% in dark. When the electrogenic pump was poisoned with dicyclohexylcarbodiimide (DCCD) the current-voltage curve moved by about 50 mV (depolarized) along the voltage axis curve and finally converged with the curve for passive diffusion channel. Depolarization of the membrane potential, decrease of membrane conductance, and decrease of the pump current during pump inhibition by DCCD are caused mainly by decreased conductance of the pump channel. The decreased pump conductance may be primarily caused by a decrease in the rate constant for releasing  $\text{H}^+$  to the outside.

#### - Membrane Fluidity, Axonal Flow, and Plasma Streaming

Transport of materials within excitable membranes and cells and membrane fluidity are important aspects of excitable tissue function. Permeabilities, movement of active materials, and electrical activity are influenced by the status of the membrane.

Myrmicacin (3-hydroxydecanoic acid) which is a secretion of a South American leaf-cutting ant, depolarizes squid giant axon membrane when added to artificial sea water (10-300 ppm) and eventually blocks the action potential. The peak of the  $\text{Na}^+$  current is reduced, but there is no effect on  $\text{K}^+$  current (or channel). The effects of myrmicacin are reversible. Myrmicacin-like hydrocarbon chains, fatty acids with less than eight carbons, had no effect while nine or ten carbon chains gave an effect. The effect is therefore related to the number of carbon atoms and also appears to be related to the structure of the molecule. The speculation is that myrmicacin gets into the lipid layer of the membrane and increases membrane fluidity and thereby perturbs membrane lipids and  $\text{Na}^+$  channel lipoprotein. Fatty acids applied externally to the membrane also have effects. Valeric acid decreased membrane fluidity while 2-decanoic acid increased fluidity.

The movement of particles in membranes is influenced by colchicine. Using high contrast video techniques, it was found in chick tissue cultured neurites that colchicine disrupts microtubules and particles stop in the swollen region of the neurite (at the end of the disrupted microtubule).

Nutrients from the cell body of the neuron to the axon and dendrite are transferred by axonal flow. Injected radioactive ACh or  $\gamma$ -aminobutyric acid (GABA) into the cell body of a cholinergic neuron of *Aplysia kuroda* moved down the axon 2.5 mm/hr at 20°C. Colchicine suppressed the movement but some passive movement occurred (diffusion). GABA had the same effects as ACh. GABA, synthesized from injected

glutamate in the photoreceptor cell of the barnacle (*Balanus eburneus*) travelled down the axon and reached the terminal within several hours. The results support the notion that the transmitter substance of the photoreceptor cell is GABA. There is further evidence from other experiments with the barnacle. Light produces membrane depolarization in the photoreceptors which spreads electronically toward the presynaptic axon terminal. The receptor potential activates  $\text{Ca}^{2+}$  channels at the terminal and acts to release the synaptic transmitter. Synaptic action of the photoreceptor cell is inhibitory and the photocell transmitter appears to be GABA.

Cytoplasmic streaming is influenced by pH. At pH 7 streaming seems to be maximal and at pH 8.5-9 is lower and almost zero at pH 5-5.5. The membrane potential is most negative at pH 7.

#### SUMMARY

This report is intended to provide the reader a review of most of the current research being conducted in Japan in the neuroscience and membrane physiology areas. The presentation of the material was made without regard to author, i.e., in any given section the work of several authors is intermixed. The intent was to have each section include the most pertinent work done over the last two to three years. In some cases, older work is included. The division of material is completely arbitrary and much of the research could very well have been included in other, perhaps more appropriate, sections. Since not all researchers active in these areas were visited, the report is incomplete and should be updated when additional material is available.

# APPENDIX

SCIENTIST	INSTITUTION	AREA OF RESEARCH
Dr. Y. Kanno	Department of Physiology, School of Dentistry, Hiroshima University, Hiroshima	Cell-to-cell coupling
Dr. I. Seyama	Department of Physiology, School of Medicine, Hiroshima University, Hiroshima	Toxin effects
Dr. R. Ochi Dr. N. Hino	Department of Physiology, School of Medicine, Juntendo University, Tokyo	Ionic channels
Dr. S. Hashimura Dr. T. Gotow	Department of Physiology, School of Medicine, Kagoshima University, Kagoshima	Histamine effects
Dr. N. Miki	Department of Pharmacology, Cancer Research Institute, University of Kanazawa, Kanazawa	Toxin effects
Dr. C. Yamamoto	Department of Physiology, Faculty of Medicine, Kanazawa University, Kanazawa	Brain slices, neurotransmitters
Dr. K. Morimoto	Department of Physiology, Medical School, Kumamoto University, Kumamoto	Neurotransmitters
Dr. S. Ito Dr. E. Sato	Department of Biology, Faculty of Science, Kumamoto University, Kumamoto	Embryonic epidermal potentials
Dr. K. Yonemura	Department of Physiology, School of Medicine, Kumamoto University, Kumamoto	Poison effects on transmission

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# GaAs MATERIALS TECHNOLOGY IN JAPAN: BULK CRYSTALS

Yoon Soo Park

## INTRODUCTION

In recent years, activities related to the growth, processing, and characterization of GaAs and related III-V compound semiconductors have increased because of the need for large-scale, high speed, and highly complex integrated circuits for applications in microwave signal processing, computer and optical fiber communication systems. In response to this increased interest and challenge, the Japanese government, in 1980, embarked on several ambitious national projects supporting basic research which is aimed at pushing forward this technology in which various research and development activities involving GaAs and other III-V compound semiconductors are being intensively pursued. In programs, for example, like the supercomputer project, the optoelectronic project, and the next generation industries semiconductor project, III-V compound semiconductors have received significant support and major advances have been made in materials growth, characterization, and device processing and fabrication.

In the area of materials growth, concerted efforts in the improvement of the horizontal Bridgman (HB) and liquid-encapsulated Czochralski (LEC) techniques of growing GaAs bulk crystals have resulted in semi-insulating GaAs substrates of large diameters (two-four inches) with thermal stability and low defect density. With the advent of new layer structure devices such as the high electron mobility transistor (HEMT) and the quantum well (QW) laser, which offer performance levels that are superior to those of conventional devices, the growth technologies of ultrathin, multilayer structures such as molecular beam epitaxy (MBE) and metal-organic chemical vapor deposition (MOCVD) have also progressed. High quality and reliable epitaxial III-V layer structures are being produced and several types of new layer structures are constantly being developed. Every industrial and university laboratory in Japan is now equipped with a MBE or MOCVD system or both.

In this report, an overview of Japanese research and development activities in the growth of GaAs bulk crystals which form the basis of GaAs integrated circuit (IC) development is presented. With progress in digital and monolithic microwave ICs and the Japanese push toward the development of an optoelectronic integrated circuit (OEIC), renewed interest in the quality and homogeneity of both semi-insulating (SI) and semiconducting crystals is being generated. An example of this interest is reflected in the number of papers presented at the 1984 spring meeting of the Japan Society of Applied Physics (JSAP), which was held 29 March-2 April 1984 on the campus of Meiji University in Tokyo. There were 42 papers dealing with GaAs bulk crystal growth and evaluation.

In anticipation of the commercial production of GaAs ICs, OEICs and demands in optical semiconductor devices such as lasers, LEDs, and photodetectors to be used in optical fiber communication systems, and in other consumer applications such as optical lasers for video and audio discs and laser printers, a dozen manufacturers have recently entered the GaAs crystal growth business (see Appendix I). These firms are currently concentrating on supplying two-inch substrates but they are also actively engaged in the development of three-inch substrates for marketing. They hope to improve the quality and to reduce the cost of substrate materials. Of those 12 companies, only six (Sumitomo Electric Industries, Mitsubishi Monsanto, Mitsubishi Metal, Hitachi Cable, Sumitomo Metal and Mining and Furukawa Electric) are currently marketing the two-inch and three-inch substrates.

Beside these commercial manufacturers, intensive research on growth, processing, and characterization of GaAs crystals is being conducted at the Optoelectronics Joint Research Laboratory (OJRL) in Kawasaki, the Atsugi Electrical Communication Laboratory of Nippon Telegraph and Telephone Public Corporation (NTT), the Toshiba R&D Center and the Electrotechnical Laboratory in Ibaraki.

#### - Crystal Growth Technology

Japanese requirements and the present status of R&D of semi-insulating GaAs substrates for GaAs IC and OEIC applications are summarized in Table I.

To attain the goals shown in Table I, Japanese laboratories and manufacturers are pursuing research and development of GaAs growth technology both by the horizontal Bridgman (HB) technique, including gradient freeze (GF), and the liquid-encapsulated Czochralski (LEC) technique.

In general, research on crystal growth is aimed at achieving:

- large diameter crystals,
- reduction and homogeneous distribution of residual impurities,
- reduction of crystalline defects--etch pit density (EPD),
- improvement of semi-insulating properties.

In the following section an account of crystal growth activities is summarized of both HB and LEC methods which is based on observations made by the author during visits to laboratories and from information extracted from technical meetings. Institutions visited, the names of scientists contacted, and the meetings attended are listed in Appendices II and III.

#### HORIZONTAL BRIDGMAN (HB) METHOD

The HB method is one of the most successful methods of GaAs crystal growth. In Japan the technique has become in essence a monopoly of Sumitomo Electric Industries, Ltd., which is the largest supplier in the world of a variety of III-V bulk crystals grown using the HB method. However, companies like Hitachi Cable and Mitsubishi Monsanto are also developing the gradient freeze technique. Sumitomo Electric has about 100 HB reactors devoted to the production of low EPD GaAs wafers in their production facility. No such production capability exists in the United States. To meet consumer demand, Sumitomo is constructing an additional plant in order to boost production capacity to five times the current level.

The three-temperature zone horizontal Bridgman (3T-HB) method developed by Sumitomo is widely known in the industry and is used for supplying GaAs wafers as production quality for various devices and IC applications. Because of the inherent advantages of the HB method in producing low EPD crystal, in addition to their LEC growth efforts, they are also exerting extensive effort in producing low EPD, large diameter (two-three inches), round-shaped wafers for laser-grade and IC-grade substrates.

#### - Large Diameter Crystals

In order to meet processing requirements and based on processing cost considerations, attempts are being made to produce round two- and three-inch diameter wafers. Boat-grown crystals appear in D- or U-shaped wafers when cut [100] direction

from a [111] grown ingot. Two-inch diameter round wafers are cut usually from D-shaped [100] wafers with an area of 30 cm<sup>2</sup> and three-inch diameter are cut from [100] U-shaped wafers of 8x10 cm with little cutting loss. Also [100] rectangular ingots are produced for laser-grade substrates. A typical round cutting process involves slicing of [100] wafers from a [111] ingot, the stacking of D-shaped [100] slices with wax after OF (orientation flat) processing of each D-shaped slice, and the finally cutting by using centerless grinding. Recently, Sumitomo has successfully grown an ingot weighing 8.8 kg with 80-90 mm width and 600 mm length.

#### - Residual Impurities

Horizontal Bridgman GaAs single crystals are routinely grown in quartz (SiO<sub>2</sub>) boats of high purity. However, undoped crystals grown in quartz boats are generally contaminated with Si of 5 to 10 x 10<sup>16</sup> cm<sup>-3</sup>. To suppress Si contamination from the quartz boat, As<sub>2</sub>O<sub>3</sub> is placed in the reaction tube. The effect of added oxygen is the formation of gaseous products of SiO<sub>2</sub> and Ga<sub>2</sub>O with Si from the boat. A diffusion barrier provided between high temperature zone (T<sub>1</sub>) and low-temperature zone (T<sub>2</sub>) in the 3T-HB furnace prevents gaseous products in the T<sub>1</sub> zone from diffusing out. Thus, Si contamination from the boat is effectively suppressed. Residual Si concentration in As<sub>2</sub>O<sub>3</sub>-doped GaAs is found to be less than 1 x 10<sup>16</sup> cm<sup>-3</sup> as analyzed by spark source mass spectrometry (SSMS).

Single crystal growth in the 3T-HB furnace is being carried out using presynthesized high purity polycrystals as starting materials. The polycrystals were synthesized from 6N Ga and 6N As. Undoped crystals had a carrier concentration of 2.4 x 10<sup>16</sup> cm<sup>-3</sup> and a Hall mobility of 4.6 x 10<sup>13</sup> cm<sup>2</sup>/V.S. while oxygen doped crystals exhibited a carrier concentration of 2.0 x 10<sup>12</sup> cm<sup>-3</sup> and a Hall mobility of 5.0 x 10<sup>9</sup> cm<sup>2</sup>/V.S.

Sumitomo has tried to grow the crystals using a PBN boat instead of the quartz boat. They were able to obtain an ingot with a carrier concentration as low as 10<sup>14</sup> cm<sup>-3</sup> and a mobility as high as 6 x 10<sup>9</sup> cm<sup>2</sup>/V.S.

#### - Crystalline Defects-EPD

Because of the relatively low temperature gradient involved at the liquid-solid interface (approximately 1-5°C/cm) compared with that of the usual LEC technique (50-100°C/cm), low dislocation density crystals are readily produced by the HB method. For example, in laser-grade, state-of-the-art HB grown, n-type crystals of two-inch diameter, an EPD of less than 500 cm<sup>-2</sup> is achieved with approximately 10<sup>18</sup> cm<sup>-3</sup> Si. The average EPD of three-inch diameter Si-doped GaAs is about 3000 cm<sup>-2</sup> at the seed end and 5000 to 10,000 cm<sup>-2</sup> at the tail end.

For Cr-0-doped, semi-insulating (SI) GaAs of 40-mm grown in the HB furnace, EPD less than 2000 cm<sup>-2</sup> the entire length of 55 cm, from the end of the seed to the tail end, has been reported. For three-inch diameter crystals an average EPD of approximately 5000 cm<sup>-2</sup> is the best result obtained so far.

Low EPD (less than 500 cm<sup>-2</sup>) GaAs substrates are only available by heavy Si doping. However, low EPD growth of heavily Si-doped (>10<sup>18</sup> cm<sup>-3</sup>) GaAs is believed to cause faceting phenomenon resulting in microprecipitate formation in the faceted area.

### - Semi-insulating Properties

Undoped semi-insulating GaAs is not available using the HB method. To produce semi-insulating properties, GaAs is doped with Cr and O. Sumitomo has recently developed three-inch diameter, low Cr-doped HB GaAs for IC substrate applications. They have doped with Cr of 0.05-0.39 wt. ppm and oxygen of  $1.1 \times 10^{-5}$  mole fraction. The residual Si concentration is found to be less than 0.1 ppma. The radial distributions of EPD show fairly uniform profiles across the entire wafer area. Thermal stability of the wafer has also been confirmed after heat treatment in an  $H_2-N_2$  gas atmosphere 800°C for 30 minutes.

Scientists at Sumitomo are continuing their efforts to achieve precise stoichiometry control and optimization of axial and radial temperature profiles around the liquid-solid interface, as well as to utilize impurity hardening phenomenon in order to improve the crystalline quality of large diameter semi-insulating and semiconducting GaAs that will be useful for IC applications. The use of a PBN boat is also envisioned for the growth of undoped SI GaAs using the HB method.

### LEC METHOD

Other than the effort using the HB growth method for GaAs bulk crystal by Sumitomo, a majority of institutions involved with GaAs growth for research and development or for production are pursuing the LEC method using either the high or low pressure system. The LEC method is being studied because it has the advantages of growing:

- high purity, undoped semi-insulating single crystals, and
- round and large diameter wafers.

However, because of the large thermal stress induced due to high temperature gradients (50-100°C/cm) at the liquid-solid interface, the LEC grown crystals tend to have higher dislocation density than the HB grown crystals. Recently, workers at NTT have demonstrated that threshold voltages ( $V_{th}$ ) of GaAs field effect transistors (FETs) fabricated on an LEC grown wafer were influenced by dislocations. There appears to be a correlation between the distribution of FET characteristics and EPD. Therefore, there are intensive efforts being made in trying to reduce the dislocation density in semi-insulating crystals.

The following approaches are generally being detected in the activities of Japanese laboratories:

- lowering of temperature gradients,
- magnetic field application--vertical (parallel to the crystal pull direction) and horizontal (vertical to the pull direction),
- As pressure control,
- addition of isoelectronic impurities.

### - Large Diameter Crystals

There is a flurry of reports concerning the successful development of three-inch diameter substrates by GaAs crystal makers. Hitachi Cable, Sumitomo Electric Industries, and Furukawa Electric began marketing LEC grown three-inch diameter wafers. At the 1983 fall meeting of the Japan Society of Applied Physics (JSAP), OJRL



announced the successful growth of four-inch diameter wafers by CADC. For practical purposes, as demonstrated by Japanese requirements, manufacturers are centering on the development of three-inch diameter wafers with  $\pm 0.75$  mm tolerances. Commercially available two-three inch diameter wafers call for  $\pm 1-5$  mm tolerances, though at the laboratory level the diameter is controlled within  $\pm .5$  mm tolerances (1%) accuracy for two-inch diameter wafers.

Precise control of the crystal diameter is achieved by applying computer automated diameter control (CADC). Extensive use of the CADC technique reflects the present Japanese effort to achieve good uniformity and reproducibility of shape and quality of each wafer and ingot which is necessary to obtain a highly integrated circuit without waste.

With the CADC technique, several important parameters which are measured during growth are fed into the computer and processed in real time to overcome the instability characteristics of the GaAs melt. The crystal diameter is computer controlled using a precise buoyancy correction weight signal and by the compensation of a large time lag and anomalous weight response corresponding to the temperature variation. As a result, for example, workers at the Optoelectronics Joint Research Laboratory were able to produce large [100] oriented GaAs single crystals of two-four inches in diameter regulated within  $\pm 1.5\%$  in the temperature gradient of  $50^\circ\text{C}/\text{cm}$ .

#### - Residual Impurities

One unique approach to minimize residual impurities in grown crystals was observed at OJRL. The laboratory is using the new *in situ* melt purification technique to reduce the background concentration of Si in undoped GaAs. In this new technique, the melt is purified by *in situ* distillation. The *in situ* distillation process involves the abrupt reduction of the high Ar pressure inside the growth chamber to near atmospheric pressure causing bubbling in the molten  $\text{B}_2\text{O}_3$ . During the bubble evaporation, which is mainly of gaseous water vapor, some impurities such as Si evaporate from the melt in the form of gaseous  $\text{SiO}_2$ . In addition, the electrical conductivity of the GaAs melt is monitored by alternating electric current (15 V and 50 Hz). It is found that there is a strong correlation between the melt conductivity, the degree of the melt purification, and the resultant resistivity of the crystal. For example, to obtain undoped semiconducting crystals, the current in the melt should be less than 0.5 mA with pressure of 20 atm prior to the pulling initiation. In this way, undoped semi-insulating crystals with a low Si concentration ( $5 \times 10^{14} \text{ cm}^{-3}$ ) are reproducibly grown using either PBV or  $\text{SiO}_2$  crucibles.

#### - Crystalline Defects-EPD

It is generally believed that higher dislocation density is observed in LEC GaAs than in HB GaAs. This is due to thermal stress induced by nonuniform temperature distribution in the crystal during the growth process and as a result of a severe temperature environment encountered by the introduction of high pressure gas and the use of  $\text{B}_2\text{O}_3$  encapsulants. In order to reduce the EPD density in grown crystals various approaches, such as the lowering of temperature gradients at the liquid-solid interface, the application of magnetic fields, As pressure control, and the addition of isoelectronic impurities are being implemented.

To reduce the temperature gradient of the  $\text{B}_2\text{O}_3$ -GaAs melt interface, variations of the following parameters are being tried:

- location of the crucible,
- ambient gas pressure,
- ambient gases,
- modification of the furnace (use of thermal baffles and susceptor windows),
- thickness of  $B_2O_3$ .

For example, for the conventional LEC technique the axial temperature gradient was decreased from 65 to 35°C/cm as the  $B_2O_3$  thickness was increased from 15 mm to 30 mm. With the use of susceptor windows and thermal baffles, which enhances heating of the  $B_2O_3$  layer, the temperature gradient near the interface is further reduced to 10-25°C/cm in the axial direction and 5°C/cm in the radial direction. As a result of the reduction in the temperature gradient, considerable reduction in EPD has been achieved.

Another example; at the temperature gradient of 25°C/cm (20 atm,  $B_2O_3$  - 30 mm, susceptor window) EPD was decreased to  $1 \times 10^4 \text{ cm}^{-2}$  from  $5 \times 10^4 \text{ cm}^{-2}$  in the conventional case and EPD distributions were changed to U-shape from W-shape. At 15°C/cm, (20 atm, susceptor windows plus thermal baffle), EPD was decreased to 3000  $\text{cm}^{-2}$ . By reducing the pressure from 20 atm to 5 atm, EPD was further decreased to approximately 1000  $\text{cm}^{-2}$ . The crystals grown under low pressure and low temperature gradients are in general characterized by U-shape distributions, while the crystals grown in high pressure (>20 atm and high temperature gradient, approximately 100°C/cm) show W-shape distributions.

Dislocation densities are also influenced by different ambient gases and it was found that the effect of ambient gases is to decrease the EPD in the order Kr, Ar,  $N_2$  and He.

Another approach to reduce the dislocation density in LEC GaAs used by NTT workers was to grow the entire crystal immersed in  $B_2O_3$  liquid. In this method, a thick  $B_2O_3$  encapsulant which has a thickness greater than the final length of the crystal to be grown is prepared. Therefore, the crystal is not pulled outside the  $B_2O_3$  during the growth process. The idea was to minimize the radial temperature difference at the region near the interface between the  $B_2O_3$  encapsulant and the inert gas atmosphere. In this way they were able to extend the dislocation-free region of the crystal to 10 mm in comparison with the 3 or 4 mm dislocation-free region of the crystal grown by the conventional LEC method.

Extensive research on magnetic field assisted growth of GaAs using vertical and horizontal magnetic fields (OJRL and Sumitomo) and vertical magnetic fields (NTT) is being conducted. The application of the magnetic field to the melt during the growth of silicon has been known to improve the crystal quality through controlled oxygen concentrations. However, there has been no report on the effect of the magnetic field on the growth of GaAs single crystals.

Through Japanese scientists efforts, it is now being established that through the application of a magnetic field to the growth of GaAs single crystals:

- growth striations caused by thermal convection can be eliminated,
- contamination of B and Si impurities from crucibles can be lowered,
- fast pulling speeds can be applied, and
- low dislocation density can be obtained.

The first two effects have already been demonstrated in the magnetic field assisted Czochralski (MCZ) growth of homogeneous and high purity Si crystals. The remaining effects can be considered unique in the magnetic field assisted LEC (MLEC) growth of GaAs.

At OJRLs, a horizontal MLEC puller consists of an in-house modified Cambridge Instruments MSR-6RA high-pressure puller and a superconducting field generator which is capable of delivering up to 3000 G. A vertical MLEC puller consisting of a Melbourne high-pressure puller and a superconducting magnet delivers up to 5000 G. In the horizontal MLEC puller, temperature fluctuations of approximately 18°C are observed in the melt when no magnetic field is applied; however, the fluctuation decreased to approximately 1°C at 1300 G when the field is applied. In the vertical MLEC puller, the fluctuation decreased to approximately 0.1°C at 1000 G for a 1 kg charge in the four-inch crucible and the fluctuation suddenly started decreasing at 500 G, becoming approximately 0.1°C at 1000 G for a 3 kg charge in the six-inch crucible. With the exception of such effects as observed in the melt, the difference in the characteristics of grown crystals in the two different magnetic fields has not yet been established.

In NTT's (Atsugi ECL) high-pressure vertical MLEC puller, a vertical magnetic field of up to 2000 G is generated by a 200 kg water-cooled solenoid surrounding a 500 mm chamber.

Japanese scientists at OJRL have successfully grown, for the first time, undoped, [100] oriented, two-inch diameter GaAs single crystals in the presence of a 1300 G magnetic field (horizontal) with 20 atm pressure of argon using the direct synthesis technique with either PBN or SiO<sub>2</sub> crucibles. A crystal was pulled at the rate of 9 mm/h and rotated at 0-10 rpm. The crystals grown in the presence of the magnetic field without the crystal rotation were striation-free and had low dislocation density (3000-8000 cm<sup>-2</sup>). This loss of growth striation in the solidified crystal is due to a reduction of thermal convection in the melt under the influence of the magnetic field. However, an undoped, semi-insulating crystal obtained from a PBN crucible exhibited n-type conductivity as the magnetic field was applied during the growth period. The resistivity of the crystal was about 10 Ω-cm at 1300 G.

When the crystals grown in the magnetic field were examined by photoluminescence (PL) and deep-level transient spectroscopy (DLTS) methods, the concentration of EL2 was reduced considerably indicating that the decrease in resistivity must be due to the decrease in deep-level concentrations.

As the pulling speed of the crystal was increased in the magnetic field from 9 mm/h, the resistivity of the crystal was changed from semiconducting (10-100 Ω-cm) to semi-insulating (10<sup>8</sup> Ω-cm) at 18 mm/h for the PBN grown crystals and at 36 mm/h for the SiO<sub>2</sub> grown crystals.

At a low pulling speed of 9 mm/h, a minute addition of Cr 0.007 wt. ppm was needed to change the conductivity of the crystal from semiconducting to semi-insulating. The resistivity of this superlow or (an order of the magnitude lower than the Cr content of Cr doped LEC crystals) exhibited remarkable uniformity from the top to the tail of the crystal ingot.

Research efforts by Japanese scientists are continuing to find the effects of both vertical and horizontal magnetic fields on both GaAs melt temperature distributions and the homogeneity of LEC GaAs crystals.

#### - As Pressure Control

An effort to grow GaAs crystals under As pressure control, without the use of B<sub>2</sub>O<sub>3</sub> encapsulants, in the pressure furnaces is being carried out at the Central Research Institute, Mitsubishi Metal Corporation at Omiya. The crystals grown in the PBN crucible at the As pressure control temperature of 616°C exhibited U-shaped EPD distributions and EPD of approximately  $2 \times 10^3 \text{ cm}^{-2}$  in the center region of the two-inch diameter wafer. The results are encouraging and by using this technique it is expected to achieve low temperature gradients at the liquid-solid interface.

#### - Addition of Isoelectronic Impurities

To reduce the EPD in semi-insulating (SI) crystals, there has been an attempt to dope with isoelectronic impurities such as Al, N, B, Sb and In. In the LEC method, the addition of impurities is believed to increase the bonding energy of crystal lattices and to produce impurity hardening effects. There is a report made by Soviet workers of achieving SI GaAs with a resistivity of  $10^8 \Omega\text{-cm}$  and a dislocation density of less than  $1000 \text{ cm}^{-2}$  with In doping in the range of  $2\text{-}5 \times 10^{19} \text{ cm}^{-3}$  using the LEC method.

At the 1984 spring meeting of the Japan Society of Applied Physics, there was a report on In doping in SI LEC GaAs crystals. They observed a region with the EPD of  $0\text{-}100 \text{ cm}^{-2}$  in 30-40 mm diameter crystals. At the recent technical meeting on "Current Status and Future Prospects of the Growth of Low Dislocation Density LEC Crystals," (14 May 1984), workers at NTT also reported on their work on Al, N, In doping and workers at OJRL on In doping in LEC GaAs. With Al doping, they have seen a reduction in EPD but a loss of semi-insulating properties in LEC GaAs. For N doping crystals, twinning was observed. With In doping both NTT and OJRL workers observed a reduction in EPD without a loss of semi-insulating properties. An EPD of approximately  $1000 \text{ cm}^{-2}$  was observed in In doped, SI LEC GaAs but EPD distribution was inhomogeneous.

As shown in HB grown crystals, low EPD ( $<500 \text{ cm}^{-2}$ ) was also observed in Si doped LEC GaAs by OJRL workers. Infrared LEDs fabricated from both LEC and HB crystals have exhibited nearly comparable characteristics as shown below:

	LEC	HB
EPD ( $\text{cm}^{-2}$ )	600	$<500$
Carrier concentration ( $\text{cm}^{-3}$ )	$9 \times 10^{17}$	$1.1 \times 10^{18}$
Peak wavelength ( $\mu\text{m}$ )	947	947
Current density ( $\text{A}/\text{cm}^2$ )	4	4
Output power (arbitrary)	494	487

#### - Crystal Evaluation

Throughout Japan, comprehensive and thorough material characterization activities are being performed and strong emphasis is being placed on the correlation of results of materials characterization and device characteristics. Bulk crystal growth processes is closely coupled with the evaluation of grown materials. Extensive research on the identification of defects and residual impurities in undoped, or low Cr doped LEC GaAs is underway.

In particular, there are strong efforts to improve inhomogeneous performances of FETs fabricated on LEC crystals. There are increasing research activities in

inhomogeneities with regard to EPD distributions, EL2 concentration and leakage current variations in the substrates, and threshold voltage distribution in FETs fabricated on the substrates. Recently, workers at NTT have clearly demonstrated by the direct measurement of threshold voltages of FETs around dislocations that there is a definite correlation between FET threshold voltage ( $V_{th}$ ) variations and EPD distributions in LEC GaAs. In their work, LEC grown, low Cr doped, two- and three-inch diameter GaAs having the EPD of  $10^8 - 10^9 \text{ cm}^{-2}$  and W-shaped EPD distributions were implanted with 60 keV,  $2 \times 10^{12} \text{ cm}^{-2}$  Si, and annealed at 800°C, 20 min with a  $\text{Si}_3\text{N}_4$  cap in flowing  $\text{N}_2$ . MESFETs with a 1  $\mu\text{m}$  gate length, 5  $\mu\text{m}$  gate width and 6  $\mu\text{m}$  source-drain distance were fabricated at an interval of 200  $\mu\text{m}$  over the entire wafer area. They found that FETs located at distances less than 20-30  $\mu\text{m}$  from a dislocation exhibited a threshold voltage of 300 mV lower than that of FETs located far from a dislocation. The distance of 20-30  $\mu\text{m}$  corresponds to the radius of the so-called "denuded zone" surrounding dislocations. The work emphasizes the importance of elimination or control of dislocation in LEC GaAs for IC applications.

Large efforts are being seen in the attempts to understand the "physics of semi-insulating substrates." For example, Japanese scientists are working hard to unravel the origin and character of deep centers such as EL2 in SI substrates. At the meeting of the 1984 International Workshop on III-V Compound Semiconductor Materials and Devices (WCSMD) held 2-4 February 1984 at Shimoda, an entire half-day session was devoted to the discussion of deep levels in GaAs. About 140 participants earnestly discussed topics such as:

- Real atomic structure of 'EL2': Impurity or native defects?
- How to measure and observe 'EL2'?
- When, where and how is 'EL2' born during growth?
- How does it change during heat treatment?
- Any correlation with dislocation?
- What is its role in the compensation mechanism of semi-insulating crystal?

Questions presented may sound "old" to many American scientists but Japanese scientists are persistent in pursuing the solution of the "old" problems and they are "in a true sense" trying to get to the bottom of them. They hope to solve the existing substrate problems in order to produce breakthroughs in basic materials technology.

#### DISCUSSION AND SUMMARY

In response to the needs for GaAs ICs and OEICs, Japanese laboratories and manufacturers are undertaking major efforts to produce large, round-shaped homogeneous GaAs single crystals with low dislocation density, low residual impurities, and thermal stability. They are concentrating on developing reproducible and controlled growth techniques for crystals for GaAs IC and optoelectronic devices. Materials of interest include both semi-insulating and semiconducting substrate crystals. These crystals are currently being grown by both horizontal Bridgman (HB), including gradient freeze (GF), and liquid encapsulator Czochralski (LEC) techniques.

Major advances are being made in producing high quality (low dislocation density and low residual impurities) crystals. For example, recently Sumitomo Electric Industries announced the growth of dislocation-free undoped, semi-insulating GaAs crystals using the LEC technique. The single crystals, 65 mm in diameter, have dislocation densities of 0-200  $\text{cm}^{-2}$  and resistivities in the range of  $10^7$ - $10^8$   $\Omega\text{-cm}$ . FETs fabricated by ion implantation exhibited a threshold voltage variation of  $\pm 20$  mV within the 2  $\text{mm}^2$  wafer area. Detailed technical information on growth procedures has not yet been released. The company expects to announce the details sometime in October 1984. In December 1983, the Toshiba Corporation also announced the growth of two-inch diameter SI GaAs with the EPD of less than 1000  $\text{cm}^{-2}$  using the LEC method. They were able to reduce the EPD as a result of balancing the horizontal temperature distribution within  $\pm 1^\circ\text{C}$  in the  $\text{B}_2\text{O}_3$  encapsulant by introducing an additional vertical heating system in the furnace. Their success stems from many years of experience in GaP crystal growth technology.

The perfection of growth techniques for dislocation-free GaAs substrates will have a great impact on the future of the GaAs-based electronic industry.

#### - HB vs. LEC

There is some debate on the merits of the HB technique versus the LEC technique of growing large diameter, round-shaped SI GaAs substrates for IC use. The proponents of the LEC techniques cite the HB technique shortcomings as follows:

- difficulty of obtaining round-shaped, large-sized substrates,
- difficulty of reducing residual impurities; therefore, of obtaining high purity crystals,
- difficulty of obtaining homogeneous crystals, in terms of both impurity and EPD distributions, because [100] crystals are cut from [111] grown ingots,
- cost considerations because round wafers are produced from D- or U-shaped wafers thus resulting in waste of materials.

The trend is toward the utilization of the LEC technique if the high dislocation density which is often observed in LEC GaAs crystals is drastically reduced. This is evident based on the fact that many newcomers in crystal growing are adopting the LEC technique and the existing HB crystals growers are further developing the LEC technique.

#### - Cr vs. Undoped

There are many reports and discussions on whether Cr doped or undoped substrates are suitable for GaAs IC applications. Because of the redistribution of Cr upon annealing, thermal conversion, poor activation of implanted dopants, and the large deviation of FET parameters, etc., there is a tendency to prefer LEC grown, undoped SI substrates. However, it is also reported that relatively low doped (0.05-0.3 wt. ppm) GaAs substrates show desired thermal stability and are attractive for ion implantation for GaAs IC fabrication. Therefore, there is some activity underway to achieve low Cr doped crystals using the LEC crystals. There are reports of thermal instability in undoped SI GaAs as a result of EL2 outdiffusion upon heat treatment. Many device manufacturers in Japan are, in fact, still employing Cr doped substrates for device fabrication.

In summary, large two-and three-inch diameter SI GaAs are now available commercially in Japan using both the HB and LEC techniques. In the laboratory, there are reports of growing four-inch and five-inch diameter crystals. With the HB method, semi-insulating substrates are produced by doping with Cr of 0.05-0.40 wt. ppm and oxygen of  $1.1 \times 10^{-5}$  mole fraction. Commercially available SI wafers have the average EPD of 5000-20,000  $\text{cm}^{-2}$  for HB crystals and of 10,000-100,000  $\text{cm}^{-2}$  for LEC crystals. In the laboratories, there are reports of achieving the EPD of  $<500 \text{ cm}^{-2}$  with Si doping and  $<2000 \text{ cm}^{-2}$  for SI crystals in HB crystals, and  $<3000 \text{ cm}^{-2}$  for SI crystals grown by the LEC method. Sumitomo has recently disclosed development of dislocation-free (EPD approximately 0-200  $\text{cm}^{-2}$ ) SI crystals using the LEC method.

Major advances are being made in improving crystal growth techniques as well as the quality of the crystals. However, Japanese laboratories and manufacturers are striving to develop the GaAs materials growth technology with the goals of:

- growth of defect-free crystals. Their target is to achieve the EPD of  $<1000 \text{ cm}^{-2}$  in LEC crystals. Research on stoichiometric control reduction of residual impurities is emphasized.
- uniformity and reproducibility. To achieve desired uniformity and reproducibility, there has to be a true understanding of the mechanism of semi-insulating properties in LEC crystals. For this purpose they are constantly applying new evaluation techniques to correlate growth process, materials characteristics, and device performances.
- low cost production methods. The present cost of a three-inch wafer is about fifty times the Si wafer. In order for GaAs LSI to occupy part of the Si LSI market, low cost production procedures have to be developed. Their efforts along these lines are reflected in the recent growth activity of Si-doped GaAs for LED using the LEC technique.

#### ACKNOWLEDGEMENTS

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## APPENDIX I

### III-V SEMICONDUCTOR CRYSTAL MANUFACTURERS IN JAPAN

Sumitomo Electric Industries, Ltd. 5-15 Kitahama Higashi, Osaka, 541 Japan	GaAs Substrate, GaAs EPI (FET), EPI (LED), GaSb substrate InAs substrate InP substrate InSb substrate	LEC, HB, two- and three- inch available
Mitsubishi Monsanto Chemical, Ltd. 2-5-2 Marunouchi, Chiyoda-ku, Tokyo, 100 Japan	GaAs substrate GaAs FPI (FET) GaP substrate GaP EPI (LED)	LEC, HB, two- and three-inch available
Mitsubishi Metal Corporation 1-5-2 Ohtemachi, Chiyoda-ku Tokyo, 100 Japan	GaAs substrate InP substrate	LEC, two-inch available
Hitachi Cable, Ltd. 2-1-2 Marunouchi, Chiyoda-ku, Tokyo, 100 Japan	GaAs substrate, GaAs EPI (LED)	LEC, HB, two- and three-inch available
Shinetsu Semi-conductor, Ltd. 1-4-2 Marunouchi, Chiyoda-ku, Tokyo, 100 Japan	GaAs substrate GaP substrate	LEC, under development
Showa Denko Company, Ltd. 1-13-9 Shibadaimon, Minato-ku, Tokyo, 105 Japan	GaAs substrate	LEC, under development
Sumitomo Metal Mining Company, Ltd. 5-11-3 Shinbashi, Minato-ku, Tokyo, 105 Japan	GaAs substrate GaP substrate	LEC, two-inch available
Dowa Mining Company, Ltd. 1-8-2 Marunouchi, Chiyoda-ku, Tokyo, 100 Japan	GaAs substrate	LEC, under developement



The Furukawa  
Electric Company, Ltd.  
2-6-1 Marunouchi,  
Chiyoda-ku,  
Tokyo, 100 Japan

GaAs substrate

LEC, two- and three-  
inch available

Sumitomo Chemical  
5-15 Kitahama,  
Higashi-ku,  
Osaka, 541 Japan

GaAs substrate

LEC, under  
development

The Fujikura Cable  
Works, Ltd.  
2-11-20 Nishigotanda,  
Shinagawa-ku,  
Tokyo, 141 Japan

GaAs substrate

LEC, under  
development

## APPENDIX II

### LABORATORIES VISITED

Listed below are the laboratories that were visited by the author where discussions on bulk crystal growth of GaAs and evaluations were specifically held, with those investigators who provided assistance and their specific areas of interest.

SCIENTIST	INSTITUTION	SUBJECT
Professor T. Ikoma	University of Tokyo The Institute of Industrial Science	Deep levels in GaAs
Professor H. Kukimoto	Tokyo Institute of Technology at Nagatsuda	Study of deep levels in semiconducting
Dr. T. Fukuda	Optoelectronics Joint Research Laboratories	LEC GaAs bulk crystal growth
Dr. T. Ishida	Optoelectronics Joint Research Laboratories	Deep level photoluminescence in GaAs
Dr. M. Tajima	Electrotechnical Laboratory	Photoluminescence of GaAs
Dr. S. Akai	Sumitomo Electric Industries, Ltd., at Itami	HB GaAs crystal growth
Dr. T. Nishino	Osaka University Faculty of Engineering Science	Photoluminescence of GaAs
Dr. S. Miyazawa	Atsugi Electrical Communication Laboratory, NTT	Growth of LEC GaAs crystals in magnetic fields and evaluation of substrates
Dr. Y. Okuno	Central Research Institute Mitsubishi Metal Corporation	As pressure-controlled crystal growth
Dr. T. Suzuki Dr. S. Murai	Sumitomo Electric Industries R&D Group at Osaka	Growth of GaAs by HB and LEC methods
Dr. T. Nakanishi Dr. M. Watanabe	Toshiba Corporation	GaAs crystal growth

## APPENDIX III

### MEETINGS ATTENDED

Scientific and technical meetings the author attended in which GaAs bulk crystals technology was discussed are listed below:

- Technical Meeting on semiconductors and transistors

Sponsor: The group on electron devices and the group on microwaves of the Institute of Electronics and Communication Engineers of Japan (IECE Japan)

Date: 24-25 January 1984

Place: Kikai Shinko Kaikan  
Tokyo, Japan

There were 32 technical papers presented in Japanese. The first session dealt mainly with the processing of GaAs devices and the presentations on the second day concentrated on device modeling and circuits. There were two review papers at the meeting which covered the current status on GaAs bulk crystal growth and GaAs FET device activities in Japan.

- The 1984 International Workshop on III-V Compound Semiconductor Materials and Devices (WCSMD-6)

Sponsor: Voluntary Committee (No formal organization)

Date: 2-4 February 1984

Place: Shimoda, Japan

The theme for the workshop was the "True Path for Expanding III-V Semiconductor Applications." The workshop was formed six years ago to provide a forum for Japanese scientists and engineers actively engaged in the field of III-V compound semiconductor materials and device research and development to present and discuss specifically the current problem areas in their work. This is the first time that they tried to draw participants from overseas. However, of the 135 participants there were only seven registrants (four-U.S.A., one from Korean, one from England, and one from France) from other countries. The meeting was conducted in Japanese; however, simultaneous English translation was provided to nonspeaking participants.

Topics discussed at the workshop included:

Session I: Physics of semi-insulating substrates (mid-gap deep levels in GaAs).

Session II: New characterization for better understanding.

Session III: Free discussion of R&D of compound semiconductor material and devices.

Evening Session: A. Defects introduced by processing.  
B. What is happening at III-V surfaces?

Session IV: How to make MBE perfect (difficulties in MBE: surmountable or insurmountable)

Session V: Proposal and realization of novel devices.

- The 1984 Spring Meeting of the Japan Society of Applied Physics (JSAP)

Sponsor: JSAP

Date: 29 March-2 April 1984

Place: Meiji University  
Tokyo, Japan

The meeting is equivalent to the March meeting of the American Physical Society. However, unlike the APS meeting, the presentations were of applied rather than basic research nature. Over 2000 papers were presented. A meeting of this magnitude is held twice every year in the spring and fall and draws a large number of scientists and engineers working in material sciences, devices and processing throughout Japan. Many papers represented Si LSI processes, amorphous silicon, crystal growth of III-V compounds by MBE and MOCVD, III-V devices and processing. There were about 42 papers dealing with GaAs bulk Crystal growth and evaluation.

- Technical meeting on "Current Status and Future Prospects of the Growth of Low Dislocation Density LEC Crystals."

Sponsor: The Division of Electronic Materials  
the Japan Society of Applied Physics

Date: 14 May 1984

Place: Kikai Shinko Kaikan  
Tokyo, Japan

It was a half-day meeting at which five papers were presented in Japanese. The papers presented dealt mainly with lowering of dislocation densities in LEC grown crystals of GaAs, InP,  $\text{In}_{1-x}\text{As}_x$  and GaP. To reduce the dislocation density in LEC grown GaAs, NTT workers attempted to grow the entire crystal immersed in  $\text{B}_2\text{O}_3$  liquid and were able to extend a dislocation-free region to 10 mm in comparison with the 3 or 4 mm dislocation-free region of the crystal grown by the conventional LEC method. By adding isoelectronic impurities such as In, they extended further the dislocation-free region. Workers at the Optoelectronics Joint Research Laboratory also presented their efforts in reducing the dislocation density in LEC GaAs crystals. They reported a dislocation density of  $1000 \text{ cm}^{-2}$  for undoped, semi-insulating LEC GaAs crystals of two-inch diameter grown under Ar pressure of 5 atmosphere with susceptor windows, thermal baffles and 30 mm thick  $\text{B}_2\text{O}_3$  encapsulants.

TABLE I\*

REQUIREMENT		STATUS	
		Commercial	Laboratory
Shape	round	round	round
Size	3-inch	2-3 inch	3-inch
Tolerance	3-in $\pm$ 0.75 mm	$\pm$ 1-5 mm	2-in $\pm$ 0.5 mm
EPD	$<1 \times 10^3 \text{ cm}^{-2}$	$5 \times 10^4$	$\sim 8 \times 10^3 \text{ cm}^{-2}$
		$-2 \times 10^5 \text{ cm}^{-2}$	striation
None	yes	yes-no	
Micro defects	none	?	?
Resistivity	$>10^8 \Omega\text{-cm}$	$10^7\text{-}10^8 \Omega\text{-cm}$	$10^8 \Omega\text{-cm}$
Thermal	no conversion	yes-?	yes-no
Stability	in 850°C, H <sub>2</sub>		
	60-min anneal		
Residual	$<1 \times 10^{15} \text{ atoms cm}^{-3}$	$\sim 10^{16} \text{ atoms cm}^{-3}$	$10^{15}\text{-}10^{16} \text{ atoms cm}^{-3}$
Impurities			
Uniformity	$<5\%$	not attained	not attained
Reproducibility	yes	not attained	not attained
Cost	3-5 times	about 50 times	
	Si wafer	Si wafer	

\*[Translated from an article, "GaAs Crystal Technology" by T. Fukuda, *Densi Zairyo* 22, (1) 36, (1983)]

# RADIOPHYSICS IN AUSTRALIA: RESEARCH ACTIVITIES OF THE CSIRO DIVISION OF RADIOPHYSICS

Leon H. Fisher

## INTRODUCTION

A good deal of the radiophysics research in Australia is carried out by the Division of Radiophysics of the Commonwealth Scientific and Industrial Research Organization (CSIRO). This work is described in the present report. The facilities of the division are also used by Australian universities and by overseas institutions.

The report is based on two trips to Australia which included visits to the following installations operated by the division: (1) the Australian National Radio Astronomy Observatory (commonly referred to as the Parkes Radio Telescope, since it is close to the town of Parkes) (two visits), (2) the Culgoora Solar Observatory (two visits), and (3) the headquarters of the division in Epping. I also made two visits to the Siding Spring Mountain site in New South Wales which is the location of the 3.9 m optical and infrared Anglo-Australian Telescope, the U.K. Schmidt 1.2 m optical infrared camera telescope (a unit of the Royal Observatory, Edinburgh), and the Siding Spring facility of the Mount Stromlo and Siding Spring Observatory of the Australian National University. Although the Siding Spring Mountain site does not involve radio astronomy, a brief description of the facilities are given in an appendix.

## COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION (CSIRO)

The Commonwealth Scientific and Industrial Research Organization (CSIRO) was established in 1949. It replaced the Council for Scientific and Industrial Research (CSIR) established in 1926. CSIRO is a large government-supported statutory organization which carries out scientific and industrial research, largely in-house.

By law, defense and nuclear topics are excluded from CSIRO's activities since it is felt that security is inconsistent with the openness desired for its main activities. CSIRO thus carries out no secret or "classified work" of a military nature. (However, CSIR was very much involved in defense work during World War II; the CSIR Division of Radiophysics, which was established in 1940, in particular worked for the Army, Navy, and Air Force in developing and constructing lightweight transportable high performance radar sets for the South Pacific War Zone during that period.) Biological sciences and human nutrition are included in CSIRO's activities but clinical medicine is not. CSIRO does not carry out research for business (such as telecommunications services) in which the government is involved, although it responds to requests for help from such organizations.

CSIRO has a total staff of about 7500, of which about 2900 are scientists. Its activities are carried out in more than 100 laboratories and field stations throughout the country. About 2000 papers are published annually by CSIRO scientists. In 1981/82, CSIRO spent \$267.1 million on salaries, general running expenses, scholarships for students, grants to outside bodies and equipment. In addition, \$61.9 million was spent on buildings, acquisition of property, and general repairs and maintenance. The total budget for 1981/82 should correspond to a budget of about \$5.17 billion for the U.S. on the basis of the ratio of American to Australian populations.

Legislation known as the Science and Industry Research Amendment Act of 1978 reorganized CSIRO. The most interesting provisions of the 1978 act follow:

- CSIRO's main role is the planning and carrying out of research required by industry (but not research that industry should reasonably be expected to carry out by itself), the community, and other national and international interests of Australia.
- CSIRO has the responsibility of encouraging the publication, application, and use of research results. CSIRO publishes the *Australian Journals of Scientific Research* with the cooperation of the Australian Academy of Science (about two-thirds of the papers published in these journals are by non-CSIRO scientists). These journals are:

*Australian Journal of Agricultural Research,*  
*Australian Journal of Biological Sciences,*  
*Australian Journal of Botany,*  
*Australian Journal of Chemistry,*  
*Australian Journal of Marine and Freshwater Research,*  
*Australian Journal of Physics,*  
*Australian Journal of Plant Physiology,*  
*Australian Journal of Soil Research,*  
*Australian Journal of Zoology.*

- CSIRO work is carried out within organizations designated as research institutes (six have been authorized and five have been established so far).
- the former National Measurements Laboratory is now the Division of Applied Physics with a mandate not only to continue as the custodian of the national standards but also to extend work to other areas such as safety, pollution, and performance standards (there have been questions about the appropriateness of the large effort on standards by a country as small as Australia); branch laboratories of the division have recently been established in Adelaide and Melbourne so as to be closer to the main centers of manufacturing industry.
- the ability to make grants for research is now much less than it used to be.

As has already been mentioned, the activities of CSIRO are presently carried out within five research institutes. These research institutes consist of thirty-nine divisions and six smaller organizations known as units. The research institutes and the divisions and units associated with them are:

- Institute of Animal and Food Sciences

animal health  
animal production  
fisheries research  
food research  
human nutrition  
tropical animal science (in Queensland; established recently)  
molecular and cellular biology (unit)  
wheat research (unit)

- Institute of Biological Resources

entomology  
forest research  
horticultural research  
plant industry (plant biochemistry and physiology, etc.)  
soils  
tropical crops and pastures  
water and land resources (in Canberra)  
wildlife and rangelands research  
Center for Irrigation Research (Griffith, New South Wales) (unit)

- Institute of Energy and Earth Resources

energy chemistry (established in 1981)  
energy technology (established in 1981)  
fossil fuels  
geomechanics  
groundwater research (in Perth)  
mineral chemistry  
mineral engineering  
mineral physics  
mineralogy  
physical technology (unit)

- Institute of Industrial Technology

applied organic chemistry  
building research  
chemical and wood technology  
manufacturing technology  
protein chemistry  
textile industry  
textile physics

- Institute of Physical Sciences

applied physics (formerly the National Measurements Laboratory)  
atmospheric physics  
chemical physics  
computing research  
environmental mechanics  
materials science  
mathematics and statistics  
oceanography  
radiophysics  
Australian Numerical Meteorology Research Center (unit)

(The Institute of Physical Sciences receives about 20% of the total CSIRO research expenditures and also has about 20% of the total professional staff. The institute had a budget of some \$48.7 million in 1981/82; CSIRO's year starts on July 1 and ends on June 30.)



Every year CSIRO announces a new focus; in 1979/80 the focus was on manufacturing and technology; in 1980/81 it was on energy and the northern cattle industry; and in 1981/82 it was on water, land, and soil research. Seven areas have been established as being of high priority for expansion for 1983/84: advanced materials, generic manufacturing technologies, biotechnology, water and soils, plant pathology, oceanography, and information technologies. Many of the divisions and units have staffs greater than 100 and some are as large as 400.

#### DIVISION OF RADIOPHYSICS (CSIRO)

The Division of Radiophysics has been receiving about 2.4% of CSIRO'S total budget and has about 2.6% of the organization's total professional staff. Including special capital allocations, the division received \$6.7 million in 1981/82 and \$7.9 million in 1982/3. However, the discretionary funds available for research has been declining and, unfortunately, a number of curtailments in the activities of the division have occurred since August 1983. (The 1978 act gives the Institute of Physical Sciences authority on how to disburse its funds, so the curtailments would seem to be an internal decision of the Institute of Physical Sciences.) These curtailments will be delineated in the report. The division has a staff of about 200 of which 43 are research scientists and 39 are designated as experimental officers and engineers.

An internal committee reviewed the division in 1980. The review called for the strengthening of research in the application of radiophysics to community and industrial problems and for new appointments in theoretical astrophysics. Dr. R. H. Frater has been the Chief of the Division since 1980, D. N. Cooper is the Assistant Chief, and Dr. A. J. Pik is the Scientific Assistant to the Chief. The division has five main programs:

- cosmic radio astronomy,
- solar radio astronomy,
- the Australia Telescope,
- microwave techniques,
- signal and data processing.

The division has developed the Interscan system for airplanes, and this will also be described.

#### - Cosmic Radio Astronomy

Current projects include interstellar radio spectroscopy, studies of cosmic masers, extragalactic studies, especially of the Large and Small Magellanic Clouds, binary star systems, the galactic Milky Way continuum, VLBI (very long baseline interferometry), two-element synthesis telescope work, galactic CO survey, and x-band interferometry at the National Aeronautics and Space Administration (NASA) station at Tidbinbilla. Included in this work are studies of HII recombination radiation, pulsars, SNR's (supernova remnants) and quasars.

The facilities and activities of the division-operated Australian National Radio Astronomy Observatory and of the millimeter wave radio telescope at Epping are now described. (In addition, use is made of the 64 m and 34 m antennas at the NASA Space Station, Tidbinbilla, the MOST (Molonglo Observatory Synthesis Telescope of the University of Sydney) and the FIRST (Fleurs Interferometric Radio Synthesis Telescope of the University of Sydney).

## . Australian National Radio Astronomy Observatory (Parkes)

The Australian National Radio Astronomy Observatory, operated by CSIRO, is located in a very sparsely populated and radio-quiet location 24 km north of the town of Parkes in New South Wales. Parkes is a community of 10,000 people and is located 370 km west of Sydney. The observatory is located in the Goobang Valley. Work at the observatory has been described in about 4000 papers during the past twenty years; about 2500 of these were written by CSIRO staff and the rest by users.

The principal facility of the observatory is a parabolic steerable 64 m diameter dish. This is the third or fourth largest radio telescope in the world and is the largest in the Southern Hemisphere. It was completed in 1961 and was the leading radio telescope in the world for more than a decade. Modifications of the dish were subsequently made and are still going on.

The initial total cost of the telescope was about \$1.5 million. The present day replacement value is estimated to be at least \$15.0 million. About half of the funds for the construction of the telescope came from the Carnegie Corporation and the Rockefeller Foundation; the remainder came mainly from the Australian government. The Australian government has always paid for the operating costs. Specifications for the telescope were prepared by CSIRO and detailed designs were carried out, to a considerable extent, in England. The prime construction contract was given to a West German firm.

An altitude-azimuth mount was chosen in which movement in altitude is provided from the zenith to 30° degrees above the horizon. A total motion of 450° in azimuth is provided. The maximum drive rates are 24°/min in azimuth and 10°/min in altitude. A precision master equatorial unit resembling an optical telescope keeps the dish tracking an object by automatically controlling servo motors that alter azimuth and altitude. This is referred to as a master equatorial driving system.

The dish has a reflecting surface of more than three-fourths of an acre and has a focal length of 26.2 m. It has an f-number of 0.4. The dish is supported on 30 radial ribs cantilevered out from the central hub. On occasions this antenna is linked to an 18 m antenna (which is moveable on rails from 120 to 425 m north and 800 m east of the tower) and in the east-west configuration forms a two-element spectral line synthesis telescope of 800 m diameter. The weight of the dish is 300 tons. The dish must be "stowed" (placed in vertical position) if the wind is greater than 35 km/hour. It cannot be pointed accurately in wind. Stowing the telescope is not up to the judgment of the observer or driver (the telescope must have a driver as well as an observer); a computer automatically stows the telescope when the wind exceeds the permitted limit. The weight on the foundation is 1800 tons. Up to about five years ago the telescope was up about 97% of the time except for preventive maintenance for two weeks twice each year.

The height to the aerial cabin is 58 meters. The aerial cabin is supported by three legs above the focal point of the reflector and provides shelter for about 500 kg of front-end receiving equipment and working space for its maintenance. The cabin is about three meters across and is accessible by means of a small elevator in one of the tripod legs and by ladders in the other two. It was quite exciting for a layman like myself to be in the aerial cabin. (To get to the ground, the dish was tilted and I walked to the ground across the reflector!) After amplification of the signals in the aerial cabin, they are transmitted to the control room for further amplification and processing.

When the specifications for the construction of the telescope were set in the late 1950s, the most important wavelength band for radio astronomy was that centered on the 21 cm atomic hydrogen line. At that time there was not a great deal of interest in radio astronomy at shorter wavelengths. It was possible therefore to use panels of 0.8 cm mesh, woven from high-tensile steel wire and galvanized, to form the reflector surface minimizing weight, cost, and wind resistance. However, the central 17 m (diameter) surface is solid welded steel plate. The specifications on mesh dimensions and on the allowable deviations of the mesh surface from the ideal shape were set to ensure that the telescope would be usable at all wavelengths down to 10 cm; in fact, the mesh reflects 98% of the incident radio power at a wavelength of 10 cm.

Angular resolution increases at lower wavelengths and surveys of the structure and the reflecting surface showed that the structure itself was of such strength and rigidity that its potential was, in fact, far greater. In 1972, the original wire mesh panels between diameters 17 m and 37 m were replaced by perforated aluminum sheet. The aluminum sheet provided more than 98% reflectivity at all wavelengths down to about 1.3 cm.

About this time interest in the millimeter wavelength region developed and the possibility of using the central 17 m of the telescope was examined, but the accuracy of the surface of the steel plate (shaped to an rms accuracy of about 1.25 mm) was not great enough for studying millimeter waves. It was decided to use the central steel plating as a base to support a new surface consisting of 330 separate but closely-spaced panels of aluminum in seven concentric rings. Each panel has a dimension of about 1 m by 1 m. The panels are mounted a few millimeters above the steel surface. The new panel has an efficiency of more than 40% at 43 GHz (6.98 mm) and about 16% at 90 GHz (3.33 mm). The error of this surface is just under 0.3 mm.

Recently, the surface upgrading was extended to a diameter of 44 meters and tests at 22 GHz (1.36 mm) have shown the surface to have an effective tolerance of 0.9 mm rms out to 44 m. Plans were underway in November 1983 to evaluate the new surface at 8.4 GHz (3.57 cm) as part of a contract with the European Space Agency. (Parkes is collaborating with the European Space Agency in its Giotto project--a satellite mission to study Halley's Comet in 1986.) According to Jon Ables, director of the observatory, at the present time the potential frequency range of the telescope ranges from 300 MHz (1 m) to 100 GHz (3 mm). According to a report of the division for 1983/1984, the 64 m antenna is currently used for observations at frequencies in the range of 100 MHz (3 m) to 45 GHz (6.67 mm). Modern receivers have to be fitted with recirculating liquid He for cryogenic cooling. The helium is transmitted from the hub area up through a copper line to the focus of the telescope. (The division has found it desirable to set up its own cryogenic laboratory to develop a series of extremely reliable units which can be mounted on radio telescopes and which will operate continuously for many months.)

Plans were also being made to complete a major upgrade of the servo control systems on the telescope by late 1984. This was to include replacement of the metadyne system by a semiconductor-controlled rectifier system and a new microprocessor-controlled computer system.

Together with the smaller telescope (and used as an interferometer), many radio sources have been mapped at high resolution. The telescope has been used to survey the skies for radio sources, and a catalogue listing the positions and intensities (at several wavelengths) of over 8000 objects between the south celestial pole and declination +27°

has been produced. The list was compiled by first carrying out a "finding" survey at a wavelength of 75 cm (400 MHz) from which approximate positions were obtained. The sources were then observed again at 21 cm (1410 MHz) and finally at 11 cm (2800 MHz), where the telescopic beam is much narrower and allows the coordinates to be determined with an accuracy of 1 minute of arc or better.

A limited number of sources were observed during occultation by the moon, and their positions are known to within a few seconds of arc. It was the precise determination of the position of the source 3C273 made at Parkes in 1962 which led to the discovery of the first quasar.

Over four hundred radio sources have been identified with visible objects. Precise positions are available for 383 of these sources, of which roughly one-third have been identified with galaxies and one-fourth with quasi-stellar objects. For many of them, the red shifts have been measured and show the sources to be enormously far away. The remainder (over 40%) are probably galaxies too faint to be recorded on the available photographic plates.

In 1981, a 19th magnitude quasar (PKS 2000-330) was detected which has turned out to have the greatest redshift yet measured (the Anglo-Australian Telescope was used to determine the redshift). It is the most luminous and most distant object known.

Another recent discovery was the detection of a radio counterpart of the x-ray pulsar in the supernova remnant (SNR) G320.4-1.2. This is only the third pulsar to be associated with a supernova remnant. Other recent research results include the determination of elemental abundance gradients in our galaxy using radio recombination lines, detection of a water vapor maser source in the Magellanic Clouds, and detection of the first extragalactic pulsar in the Large Magellanic Cloud.

The telescope has also been used to map the direction of the galactic magnetic fields making observations of the plane of polarization of the radiation arriving at the telescope at various wavelengths. By involving Faraday rotation and its dependence on wavelength, it is possible to determine the direction of the field at the source and also the rotation effects that are produced en route.

Microwave emission by about 50 polyatomic molecules has been observed from outer space. Molecules detected at Parkes include OH, CO, formaldehyde ( $\text{H}_2\text{CO}$ ), thioformaldehyde ( $\text{CH}_2\text{S}$ ) (discovered at Parkes in 1971), methanimine ( $\text{CH}_2\text{NH}$ ) (discovered at Parkes in 1972), and methylamine ( $\text{CH}_3\text{NH}_2$ ) (discovered in 1974).

CSIRO scientists are the most frequent users of the telescope followed by observers from universities, especially the Australian National University, the University of Sydney, the University of Tasmania, the University of New South Wales, the University of Maryland, and the University of Durham (United Kingdom). Other users include observers from the European Space Agency, the Anglo-American Observatory, from one of the Max Planck Institutes in West Germany, and from an observatory in the U.S.S.R.

At the request of NASA, the radiotelescope was made available for reception of signals from the moon from the later Apollo missions. The world saw the first steps on the moon from the transmission to the Parkes telescope.

At the time of my second visit to Parkes, the major refit of the telescope and additional resurfacing had just started. The telescope is now back on the air with a remodelled control tower interior and new VAX 11/750 computer has been installed.

#### . Epping Installation

The observatory at Epping (Epping is a suburb of Sydney) is the most recent of the division's three radio astronomy observatories and was commissioned in 1976. It consists of a very accurate, steerable paraboloid of diameter four meters. It was supplied by Krupp Industries of West Germany. The operating range of the telescope is 85 to 300 GHz (3.53-1 mm).

The main reflector consists of closely fitting aluminum petals adjusted to an accuracy of 0.1 mm. The telescope optics are of Cassegrain design to enable the receiver to be conveniently mounted. Instead of placing the receiving antenna where the incoming rays would be focused by the main reflector, the rays are intercepted by a subreflector of even more precise dimensions (surface accuracy 0.03 mm) which in turn directs them onto the input of the receiver as it projects through the vertex.

Current emphasis is on studying the distribution of CO in the interstellar medium of the Milky Way and the Magellanic Clouds. CO emission is a tracer of cold, dense, molecular clouds and the results of large-scale surveys of this emission have yielded a picture of our galaxy substantially different from that based solely on 21 cm H observations. [The characteristic frequency of the  $^{12}\text{CO}$  line radiation being studied is 115.271 GHz (2.60 mm) and is the J=1-0 transition]. A recently completed survey along the Milky Way indicates that the galaxy has a four-armed structure. Dr. B. J. Robinson is the program leader for the millimeter wave telescope at Epping.

#### - Solar Radio Astronomy

Solar radio astronomy is carried out by the CSIRO at its Culgoora facility. Current research deals with the physics of radio bursts and their relations to optical, x-ray, gamma ray and interplanetary manifestations; the strength of the coronal magnetic fields out to three solar radii; the structure of solar active regions; the characteristics of particles and waves accelerated by solar flares and their subsequent behavior in the corona; and the properties of low-brightness regions of the corona (coronal holes). Theoretical work is in progress to study the growth, maintenance, and stability of plasma waves generated by electron beams in a plasma.

#### . Culgoora Solar Observatory

The Culgoora Solar Observatory is near Narrabri, New South Wales; a town with a population of about 7000 which is 400 km northwest of Sydney.

Radio observations of the sun at Culgoora are made with a four-frequency [43.25, 80, 160, and 327.4 MHz (6.94, 3.75, 1.87 and 0.916 m)] radioheliograph (an imaging radiotelescope) completed in 1967 with funds from the Ford Foundation); a wideband radiospectrograph [8-8000 MHz (37.5 m-3.75 cm)]; and a spectropolarimeter [25-700 MHz (12 m-43 cm)] which measures the circular polarization of radio bursts.

The radioheliograph provides visible TV-like dynamic images of the radio sun at the rate of one per second (for special studies up to four pictures per second can be

obtained) at the four frequencies. It consists of a ring of 96 parabolic aerials, each 13.7 meters across, spaced uniformly around a circle of diameter three km. (At the lowest operating frequency, a simpler 48-aerial ring is used.) The reflecting surfaces of the serials are made of wire mesh; crossed dipoles at the focal point of the dish enable polarization of the radio waves to be measured. The aerials are steered automatically to follow the sun for five hours per day centered around noon giving 16,000 pictures a day. The radio signals received by the aerials are transmitted to a central building where they are combined to form a visual image of the sun (or some other part of the sky). Two pictures, showing the right- and left-hand components of circular polarizations, are displayed. The frequencies were chosen so that the whole depth of the corona can be studied. Because of the height distribution of coronal electron density, the 327 MHz (0.92 m) originates mainly in the lower layers of the corona; at 43 MHz (6.98 m), radiation from 10<sup>6</sup> km or so above the sun's visible surface is being looked at. Thus, the instrument observes radio emission from the quiet sun (which is thermal in origin) as well as emission from the radio sources on the sun associated with sunspots and solar flares. (Due to budgetary restrictions, the division had to close down the operation of the radioheliograph in August of 1983. However, it is hoped that the heliograph will be recommissioned for a three-month period starting April 1984 provided that the Solar Maximum Mission satellite is repaired.)

The Culgoora radiospectrograph picks up signals from the sun by broadband antennas and receivers which are swept over the whole band rapidly so that they record the signals received at all frequencies within half a second. The instrument sweeps over the frequency range 8-220 MHz four times per second and twice per second from 220-8000 MHz. The spectrum is displayed on a screen in the form of a thin vertical line of varying brightness, the brightness of each point on the line indicating the intensity of the signal at that frequency. By photographing this trace on a slowly moving film, the result is a dynamic spectrum showing the manner in which the strength of the radio emission changes with frequency and with time. As of July 1984, the radiospectrograph will be operated by the Ionospheric Prediction Service of the Department of Science and Technology from a new location within the observatory site.

The spectropolarimeter records the sense and degree of circular polarization. The polarization is recorded on film using nine shades of color to cover the range from 100% right-handed to 100% left-handed polarization. The polarization information allows the nature of the solar magnetic fields to be deduced.

Maps of the sun at 3 mm wavelengths (100 GHz) have been made for comparison with similar maps made at other short radio wavelengths by telescopes in other countries such as the Crimean 22-meter telescope at Simeiz, U.S.S.R., and the Max Planck Institute's 100-meter telescope at Effelsburg, West Germany. These maps show details of bright regions on the surface of the sun which are associated with active sunspot regions. The radio emission comes from hot energetic electrons (energies 10-100 keV) trapped in strong magnetic fields (100-1000 G).

Although the Culgoora Solar Observatory is devoted mainly to observations of the sun, cosmic radio astronomy is also carried out there at low frequencies, i.e., 80, 160, and 327 MHz. Dr. D. J. McLean is the program leader and W. J. Payten is the officer in charge of the Culgoora Solar Observatory.

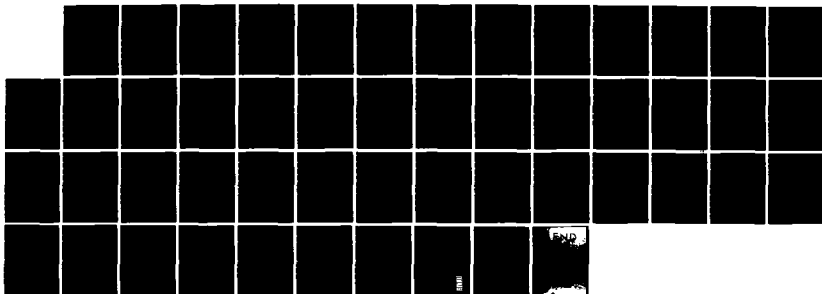
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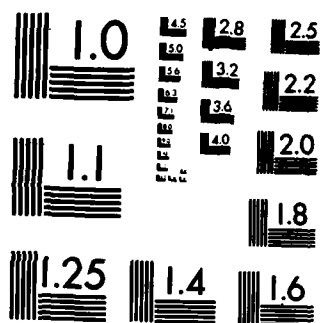
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## - Australia Telescope

Since 1975, a national steering committee has been working on proposals for a new radio telescope to cost about \$25.0 million. In 1982, the Australian government decided to fund the construction by CSIRO of a new radio telescope to be known as the Australia Telescope and to be completed by Australia's bicentennial year 1988. This is the largest amount of money Australia has ever dedicated to one scientific project. Antenna costs will account for almost half the total cost. An initial grant of \$820,000 was made available in 1982 to start the work with a commitment for funding for the following six years. It is expected that construction work will start late in 1984. The Australia Telescope will be operated as a national facility by the division from its headquarters in Epping.

The telescope will consist of three main elements and will provide high resolution radio images of the southern sky. A unique and fundamental feature of the telescope will be its ability to see the radio sky on all angular scales; that is, it will have an effective zoom ratio of 10,000:1. One of the three elements will be an east-west linear array of five 22-meter dishes at Culgoora on a 3 km rail and a sixth antenna 3 km to the west. The second element will be another 22-meter dish to be located at Siding Spring Mountain. These two elements will be linked by microwaves to the existing 64-meter telescope at Parkes.

The array at Culgoora alone will simulate a telescope 6 km in diameter; this array will allow mapping of the broader features of radio sources and investigations of spectral line emissions from giant molecular clouds in our galaxy. By itself, the 6 km array at Culgoora will be able to form radio images with detail matching the one second of arc image size of the Anglo-Australian optical telescope at Siding Spring.

Linking the Culgoora array to the Siding Spring antenna will simulate a radio telescope 100 km across. Linking the Culgoora array and the Siding Spring antenna to the Parkes dish will result in an array equivalent to a single dish with a diameter of 300 km. It will be the only instrument designed specifically for spectral line observations. It will be the only large array in the Southern Hemisphere.

With the array stretching from Culgoora to Parkes, it will be possible to complement the 0.1 second of arc images of the U.S./European Space Telescope due for launching in 1986. As such, it will be the most versatile synthesis telescope in the world. Still higher resolutions, to one thousandth of a second of arc, would be available at radio wavelengths by linking radio dishes of the Australia Telescope by satellite to other radio dishes across the continent at Fleurs (near Sydney), Tidbinbilla (near Canberra), Hobart (in Tasmania), Alice Springs (at the center of the continent) and Carnarvon (in Western Australia), thus spanning the entire 3000 km of the Australian continent. This enlarged array would be the highest sensitivity high resolution telescope in the world, an array which will recognize details 1000 times smaller than even the most powerful single telescopes can detect. This level of resolution is not obtainable at optical, x-ray, or other wavelengths.

Astronomers from the universities and observatories throughout Australia are being invited to contribute during the construction and later operation of the telescope through advisory, technical, and time assignment committees which will be set up.

At the present time, the Australia Telescope is in a hiatus period. The division appeared before a Parliamentary Public Works Committee on matters relating to the Australia Telescope on 5 September 1983. This committee is a joint Parliamentary Committee of members from both the Upper and Lower Houses and both major parties in Australia. The committee's function is to assess the timeliness and appropriateness of large public spending in any area. Parliament approved the Australian Telescope project on 17 November 1983 at an expenditure of \$30.7 million at March 1983 prices. Dr. R. H. Frater is the program leader.

#### . Microwave Techniques

Recently, three low noise receivers have been produced at widely differing frequencies, one in the L-band frequency range (near 1.4 GHz) using a cooled FET (field effect transistor) amplifier for optimum performance; one in the K-band range (near 22 GHz) employing a maser; and one in the W-band range (near 115 GHz) utilizing a cooled Schottky diode mixer. Other developments include a Q-band maser amplifier and radiometer system and a cryogenically-cooled x-band receiver utilizing a cooled GaAs FET low noise amplifier, both for the Parkes 64 m telescope. A stable x-band interferometer system for use on the Deep Space Network antennas at Tidbinbilla has been developed. Some effort is being made on the development of fabrication techniques for gallium arsenide field effect transistors (GaAsFETs) and devices for low noise work.

Horn antennas capable of operating with extremely low cross-polarization over more than one band are being developed for radio astronomy and for calibration of satellite communication systems. Work has recently been completed for the Overseas Telecommunications Commission in a project to upgrade the 27 m antenna at the Moree Earth Station for operation with the dual-polarized Intelsat V series of satellites. A new horn combining maximum bandwidth and low cross-polarization has been developed for this antenna. Work is continuing on the design, manufacture, and measurement of reflector surfaces for use at centimeter and millimeter wavelengths.

Optimally designed reflector antennas are being developed. A holographic antenna measurement range is being set up which will enable far field radiation patterns to be obtained from measurements in the Fresnel zone, as well as information about antenna alignment and surface deformation. This group is also developing an infrared locating device which enables trucks to be accurately positioned for the loading and unloading of containers at a large container terminal.

#### - Signal and Data Processing

Current projects include analysis of seismic wave propagation in coal seams using signal processing techniques developed originally for radio astronomy; new techniques for the reduction of aperture synthesis data; techniques for the analysis of physiological signals (in collaboration with the University of Sydney); development of a fast analog-to-digital system for the sampling of voice signals and design of VLSI circuitry.

#### . Interscan

Interscan, an aircraft guidance system, was developed by the division as a consequence of its experience in developing instruments for radio astronomy. Interscan will provide pilots near an airport with their positions in three dimensions. The Interscan principle was adopted in April 1978 by the International Civil Aviation Organization (ICAO) for worldwide use as the next generation aircraft guidance and

landing system. It will replace the present Instrument Landing System (ILS) in the next 10 to 20 years. Unlike conventional landing systems that guide the aircraft along a straight approach to airport runways, Interscan allows curved approaches.

Interscan is an aircraft microwave approach and landing guidance system operating in the frequency band 5130-5190 MHz (C-band). It uses two ground-based antennas near the runway which radiate narrow fan-shaped beams of microwaves which are scanned at a controlled rate. One beam scans from side to side, the other scans up and down. In a full scan, the side-to-side beam intercepts the aircraft twice, each time producing a pulse. The time interval between the two pulses is a measure of the azimuth of the aircraft relative to the runway centerline. The elevation antenna gives the elevation angle. The aircraft has DME (distance measuring equipment) which gives distance to touch down. With these three parameters, the aircraft can uniquely fix its position within the coverage sector. The system is unaffected by reflections from buildings, taxiing aircraft, hills, and uneven terrain. It can also provide guidance over a wide range of angles from the runway allowing for a variety of flight paths for both landing and takeoff in any weather conditions.

The system was being developed commercially by a government and private industry consortium, Interscan Australia Proprietary, Ltd., along with the American company, Wilcox Electric, Inc. These companies submitted a bid to the U.S. Federal Aviation Authority to supply 100 microwave landing systems for large American airports but failed to win the contract in January 1984. The division has been carrying out research on the design of multiple folded microwave lenses for Interscan and has been investigating efficient folded bends for such lenses.

#### - Collaborative Activities

##### . Collaboration with NASA

The division is collaborating with the Jet Propulsion Laboratory using NASA's Deep Space Network 64 m and 34 m antennas at Tidbinbilla near Canberra. Under this program, the two antennas at Tidbinbilla have been linked to form an interferometer which is used to determine accurate positions of radio sources. High resolutional observations using a very long baseline array (VLBA), formed by linking antennas at Tidbinbilla, Parkes, Fleurs (near Sydney), Alice Springs, and Hobart have also been carried out.

##### . Collaboration with Observatories Operating in Other Wavelengths

It is often important to complement the radio frequency observations with those made in other wavelength domains such as the infrared, visible, ultraviolet, x- and gamma ray regions. Other facilities, such as the 3.9 m Anglo-Australian Telescope and the 1.2 m optical U.K. Schmidt Telescope and the COS-B gamma ray observatory satellite, operated by the European Caravane Collaboration are used for this purpose.

##### . Giotto Mission

Giotto is the name of the spacecraft being launched by the European Space Agency to investigate Halley's Comet in 1986. The 64 m radio telescope at Parkes will have prime responsibility for receiving data from the spacecraft as it flies through the head of

the comet. From Parkes, the data will be transmitted to a satellite tracking station at Carnarvon for transmission to the European Space Operation Center in Darmstadt, West Germany. As part of this contractual arrangement, the telescope is undergoing a major upgrade which has already been described.

#### . Voyager Mission

The Voyager 2 spacecraft was launched by NASA in 1977 and will encounter Uranus in late January 1986. The data will be relayed back from the spacecraft to antennas in the U.S., Spain, and Australia. In this collaborative project, the Parkes 64 m telescope will be arrayed together with NASA's antenna at Tidbinbilla by means of a new microwave link between the two centers.

#### . Solar Maximum Mission

The division has coinvestigator status with the University of New Hampshire on an experiment with the NASA Solar Maximum Mission launched in 1980. Data from the gamma ray telescopes and the hard x-ray burst spectrometer are being obtained. The solar group at the Division of Radiophysics is currently working with the gamma ray team at the University of New Hampshire on Solar Maximum Mission and Culgoora data in order to compare features of radio and gamma ray bursts. This is expected to lead to a better understanding of the acceleration process in flares whereby electrons and ions are accelerated to energies of several hundred MeV.

#### . Very Long Baseline Interferometry (VLBI)

Five radio telescopes in Australia were linked by very long baseline interferometry with one in South Africa from 20 April to 3 May 1982 and created a high-resolution telescope with a dish diameter of 8000 km. The linkup was achieved by using atomic clocks and high-speed tape recorders to synchronize the reception of radio signals at each of the six telescopes to an accuracy of one millionth of a second. The experiment gave Australian astronomers an unparalleled view of distant star systems and other major radio sources in the southern sky. The five telescopes used in Australia are those at Parkes; the University of Tasmania near Hobart; the NASA tracking station at Tidbinbilla near Canberra; the University of Sydney's Fleurs Observatory near Sydney; and the Landsat tracking station at Alice Springs. The two major objects studied were Centaurus A and Circinus X-1.

## APPENDIX

### SIDING SPRING MOUNTAIN SITE

Siding Spring Mountain, a remote mountain in New South Wales, is 32 km from Coonabarabran, a town of 2000. Siding Spring Mountain operates as a field station that accommodates a number of telescopes of the Australian National University (a 2.3 m optical and infrared instrument was under construction at the time of my visit), the U.K. Science Research Council 1.2 m Schmidt camera telescope, and the Anglo-Australian 3.9 m telescope. Siding Spring is 240 km from Parkes and 160 km from Narrabri.

#### - Anglo-Australian Observatory

The Anglo-Australian Observatory has its central office and a laboratory in Epping and, as has already been mentioned, the observatory is at Siding Spring Mountain. The observatory is not a CSIRO installation; it is an independent organization and is funded 50% by the U.K. and 50% by Australia. Half the observing time is allocated to British observers.

The instrument, which was completed in 1974, is a 3.9 m (153") optical, infrared, and millimeter wave reflecting telescope with a focal length of 12.7 m. (Millimeter wave observations are made during the day.) The mirror itself is made of Cervit, a glass-like ceramic which has a near-zero coefficient of thermal expansion. Its surface was polished to an accuracy within one ten-thousandth of a millimeter. The light is reflected off the surface by a microscopically thin layer of aluminum, typically 120 nm thick. The aluminum layer has to be replaced approximately every 12 months and this is done within the observatory building. The mirror is lifted out of the telescope by an overhead hoist and cleaned with NaOH and copper wool to remove the aluminum. It is then fitted like a lid to a huge chamber which is then evacuated to about  $2 \times 10^{-4}$  Torr. A glow discharge is then used to further clean the surface. Then the chamber is evacuated to about  $10^{-6}$  Torr and about 100 tungsten filaments containing aluminum are used to coat the mirror surface.

In 1977, the instrument detected flashing optical light from the Vela pulsar, PSR 0833-45. Very faint double pulses were detected within the same period as the radio pulsar. With an apparent time-averaged magnitude of about 25.2, the pulsar was the faintest object that had ever been detected photoelectrically.

Much of the time of the telescope has been spent on finding and studying hundreds of quasars and measuring their red shifts. Detailed studies of the Magellanic Clouds are also under way. The telescope is being used more and more in the infrared.

#### - United Kingdom 1.2 m Schmidt Telescope

The U.K. 1.2 m Schmidt telescope is operated by the Royal Observatory, Edinburgh and was commissioned in 1973. It provides a wide-angle field of view of  $6.5^\circ$ . The spherical primary mirror has a diameter of 1.883 m and a focal length of 3.07 m. The telescope has a unique achromatic corrector plate of 1.24 m aperture which gives excellent images throughout the photographic range from ultraviolet to near infrared. Exposure times for plates varies from 60 to 90 minutes, depending on the wavelength region. The photographic plates have dimensions of 356 x 356 mm, but are only 1 mm

thick since they have to be curved in the telescope to fit the focal surface. Eastman Kodak plates are used, but they must be treated in elaborate ways such that one-third of the time is taken up preparing plates.

The auxiliary equipment includes two narrow angle full-aperture objective prisms which permit the simultaneous recording of the spectra of stars and galaxies; one prism has been in use since July 1976 while the second prism, with three times the dispersion of the first one, was first used in March 1982.

The telescope has two main uses. The primary use is the systematic surveying of the skies of the Southern Hemisphere in a variety of wavelength bands to extend the Sky Survey carried out in the Northern Hemisphere by the Palomar Observatory 1.2 m Schmidt telescope. A 0.9 m Schmidt in Chile, operating under the European Southern Observatory with headquarters in Geneva, is carrying out a survey concentrating on the red component. A second use is to provide photographs of particular objects or regions for individual astronomers. The telescope is not open to guest observers.

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## CURRENT ACTIVITIES IN JAPANESE PSYCHOLOGY

Kiyoshi Fujisawa and Paul Naitoh

### INTRODUCTION

This overview was prepared for the express purpose of helping create a greater understanding among American psychologists of the current activities in Japanese psychology. A comprehensive review of current Japanese psychology will not be attempted, however, as there are over 4000 practicing psychologists in Japan. Instead, the work of a few Japanese scientists who reported at the 1980 and 1981 annual meetings of the Japanese Psychological Association (JPA) have been reviewed to show some recent Japanese contributions to the science of psychology. Appendices to this paper were prepared to facilitate the exchange of information between Japanese and American psychologists on a person-to-person basis.

Although Dr. Kiyoshi Fujisawa and this author are physiological psychologists, we found we were too narrow in our conceptual scope of the entire realm of psychological investigative activities today. To compensate for our biased tendency, we tried as much as we could, to remain sensitive to all of the psychological issues being debated among Japanese psychologists. Dr. Fujisawa, who has been engaged in problems of special education involving the profoundly and multiple-handicapped, was helpful in widening this perspective.

#### - Current Status

Current psychological research trends were obtained from among the activities of Japanese psychologists as revealed in the proceedings of the *forty-fourth and forty-fifth* annual meetings of the JPA. The former was held for three days from 27 August to 29 August 1980 at Hokkaido University, Hokkaido, and the latter was held for four days from 17 to 20 September 1981 at the Kokuritsu Kyoiku Kaikan (National Education Center), Tokyo.

At the 1980 annual meeting of the JPA, there were, in addition to the usual individual papers, lectures by three foreign guest speakers. Traditional symposia were replaced by eight short lectures, 36 workshops (presenting platforms to discuss freely with other experts expressly defined research topics), and three panel discussions where a large number of psychologists participated in more broadly defined problem areas.

An example of a short lecture was H. Niki's presentation of "Behavior and Neuronal Activity from a Psychological Point of View." Examples of workshops were "Cerebral Potential Covariates of Behavior," chaired by Y. Kano, and "Biofeedback" chaired by H. Hirai. An example of a panel discussion is "What is 'Society' in Social Psychology?" which was chaired by J. Misumi. The participants in the forty-fourth annual meeting of the JPA included four honorary members, 1227 full members of the JPA, and 88 non-JPA members.

At the 1981 annual meeting of the JPA, no special lectures by foreign guest speakers were held. Instead of the workshops, twenty symposia were held. As in the 1980 annual meeting, it was composed of twelve short lectures and one panel discussion. The annual meeting was attended by 1507 individuals. The total number of individual oral presentations was 818.

Table I shows the number and percentage of oral presentations at the 1980 and 1981 annual meetings of the JPA grouped by topical areas. Table I also includes, for comparison purposes, similar information about papers presented at the 1970 JPA annual meeting as reported by Tanaka and England (1972).

According to Table I, the largest number of presentations at the 1980 annual meeting was in the area of sensation/perception: 99 papers, comprising 12.7% of the papers present. The next largest number of papers was in the area of physiology, brain waves, and evoked potentials, a total of 70 papers corresponding to 10.1% of the total presentation. Other major areas of study were clinical (76 papers), social (75), developmental (73), personality (72), and learning/memory (58). These subjects took up almost two-thirds of the total presentation.

At the 1981 annual meeting, however, the papers on developmental psychology comprised the largest proportion (15.2%; 124 papers), which was followed by the four research areas of learning/memory (12.1%; 99 papers), sensation/perception (11.7%; 96), physiology and its related areas (11.6%; 95), and language and its related areas (11.2%; 92).

A significant increase in social psychology papers was noted in the 1980 annual meeting. In the 1979 meeting, the largest number of presentations were in sensation/perception, followed by physiological, clinical, developmental, personality, learning, and social psychology in the order of the number of paper presentations.

The growth of psychology in Japan, particularly in the JPA, can be traced by examining the total number of papers presented at past annual meetings of the JPA. Tanaka and England (1972) revealed, in a tally of papers presented at the JPA annual meetings from 1966 through 1970, an increase from 411 papers to 580 papers. Likewise, a publication compiled by the JPA for the Twentieth International Congress of Psychology held in Tokyo in 1972, displayed the number of papers presented at the annual meetings of the JPA from 1927 to 1975. A significant increase in the number of papers was observed during the decade following the end of World War II. During 1945-1955, the number of papers jumped from the prewar, steady level of about 100 to more than 500 papers by 1955. Since that time, the number of papers sustained a slow growth to about 800 by the 1981 annual meeting, which was due more to time limitations at the annual meetings rather than to the vigor and activity of psychological research in Japan.

#### EXPERIMENTAL PSYCHOLOGY

##### - Current Studies on Perception, Sensation, and Cognition

In the forty-fourth (forty-fifth; hereafter the values corresponding to the forty-fifth annual meeting held in 1981 are given in parentheses) annual meeting of the JPA, ten (thirteen) sessions with 99 (96) papers were held under the divisional heading of sensation/perception, and three (five) sessions with 32 (33) papers were included under the divisional heading of cognition.

At the forty-fourth annual meeting, there were ten sessions in the division of sensation/perception:

- visual information processing with 11 (0) papers,
- depth perception with nine (14) papers,



- optical illusion and size perception with 10 (eight) papers,
- apparent movements and visual perception of movements with 12 (eight) papers,
- brightness perception with 12 (0) papers,
- auditory perception with 11 (12) papers,
- color vision with seven (three) papers,
- visual field and object perception with 10 (0) papers,
- eye movements 10 (six) papers, and
- tactile sensation, gustatory sensation, and time perception with 10 (0) papers.

At the forty-fifth annual meeting, four new sessions were added:

- framework of perception (eight papers),
- space perception (seven papers),
- Gestaltian constellation space of stimulations (seven papers) and,
- visual masking (seven papers).

The headings of these sessions suggests that the Japanese psychologists are more concerned with perception, while their American counterparts are more involved in the studies of psychophysics and the psychophysiology of sensation.

At the forty-fourth (forty-fifth) annual meeting, the cognition division had three sessions:

- image and pattern processing with 13 (0) papers,
- word cognition with seven (eight) papers, and
- cognition and understanding with 12 (0) papers.

One of the papers presented at the word recognition section was on the effects of horizontal masking bars on recognition of Chinese characters by H. Saito and I. Ishihara. This report was the thirty-first paper in 1980 (and the thirty-second paper in 1981) which resulted from long-term research on linguistic behavior by I. Ishihara at Kwansei Gakuin University. At the forty-fifth annual meeting, eight papers were presented under the section of laterality.

#### - Current Studies on Learning

Recent research trends in Japanese studies on the problem of learning can be observed by an examination of papers presented in six (nine) sessions with 61 (58) papers at the 1980 (1981) annual meeting of the JPA. At the forty-fourth (forty-fifth) annual meeting, these sessions were:

- behavior with eight (six) papers,
- human concept learning, discrimination learning, and learning of motor patterns with eight (0) papers,
- operant conditioning and classical conditioning with 14 papers (0),
- learning by observation and modeling with 12 (eight) papers,
- discrimination learning and avoidance learning with seven (0) papers, and
- biofeedback with 12 (six ) papers.

What was relatively new in the psychology of learning at the 1980 annual meeting were questions on biofeedback and modeling. Research on modeling involved questions related to memory, and the study of biofeedback required expert knowledge in physiological

psychology. Thus, these two studies are seemingly interdisciplinary in their nature, crossing traditional boundaries which are determined for specialization in the science of psychology.

At the forty-fourth annual meeting, biofeedback studies were on controlling the heart rate, alpha waves in electroencephalograms (EEGs), and the skin temperature of finger tips. A detailed report by Ishikawa and Robinson on biofeedback research in Japan has been published in the ONR Far East *Scientific Bulletin*, 5 (3), 23 (1980).

At the forty-fifth annual meeting, several new sessions were used to group oral presentations among which were:

- behavioral controls of aversion with 11 papers,
- schedule of reinforcement with seven papers,
- social learning or learning by observation with eight papers, and
- control of motions with five papers.

At the forty-fourth annual meeting, three sessions were held on:

- language information processings with 11 papers,
- language acquisition with 14 papers, and
- language associations and Chinese characters (kanji) information processing with 12 papers.

At the session of language information processing, K. Kobota, a neurophysiologist at the Primate Research Group at Kyoto University reported on the acquisition of artificial visual language by three African chimpanzees (*Pan troglodytes*) of about three years of age. These chimpanzees successfully learned artificial visual language consisting of eight objects (e.g., cup, ball) and five colors (e.g., red, yellow). Kobota and others attempted to grasp the process of artificial visual language acquisition applying Skinner's analysis of language.

At the forty-fifth annual meeting, two sessions were dedicated to sentence structures with 12 papers; one session dedicated to character recognition with six papers, and another session to artificial language with seven papers. Kobota and his group presented new data to show the acquisition by two chimpanzees of lexigram language which was comprised of three objects and three colors.

#### - Current Studies on Memory

At the forty-fourth (forty-fifth) annual meeting of the JPA in 1980 (1981) three sessions with 29 (41) papers were held in the research area of memory. At the forty-fourth annual meeting, three sessions were:

- memorization process with six papers,
- memory retrieval/encoding with 12 papers, and
- sentence and sentence memory with 11 papers.

At the forty-fifth annual meeting, six sessions with 41 papers were held on:

- memorization (six papers),
- memory of sentences (seven papers),

- retrieval of memory and codification (seven papers),
- rehearsal effects and mnemonics (seven papers),
- memory of meaningful materials (eight papers), and
- understanding and memory (six papers).

## PHYSIOLOGICAL PSYCHOLOGY

### - Current Studies on Physiological Psychology

At the forty-third annual meeting of the JPA in 1979, nine sessions were held on physiological psychology. They were:

- effects of destruction of the subcortical structures such as the hippocampus, caudates, and globus pallidus,
- neural mechanisms of operant behavior, where H. Niki reported on relationships between neuronal activities in the prefrontal area and reinforcement, and M. Watanabe reported on the neuronal activity of a monkey's prefrontal area in response to error trials during delayed discrimination learning,
- evoked potentials and cognition, where relationships between cognition/attention to visual and auditory stimuli and evoked potentials were discussed,
- evoked potentials and brain waves, where discussions were held on the effects of the interstimulus interval on evoked potentials, developmental characteristics of regional differences in EEGs, and brain wave variability of mental retardates in comparison with the normal,
- CNV of Grey Walter, where S. Kakigi presented a series of psychophysiological studies, and K. Itonaga reported on event-related potentials,
- biofeedback research and voluntary self-control of heart rate and of responses of the autonomic nervous system,
- vascular and electrodermal responses, where discussion was centered around finger pulse volume and skin potential activity,
- sleep and cyclic activity, where five papers discussed human sleep, and
- laterality and the influence of left or right hemisphere lesions on behavior.

An example of one of the studies discussed in Session Eight was K. Fujisawa and K. Nakamura's investigation of the effects of shortened sleep on power spectrum and coherence during recovery sleep.

Five papers presented discussions on sleep-wakefulness rhythms in rats and mice. N. Ibuka and others described the temporal structure of the suprachiasmatic nucleus and its relationship to sleep-wakefulness in mice.

In Session Nine, Y. Murofushi reported on a study of left hemisphere dominance in a color matching task in a monkey with a split brain. The split brain research initiated by R. E. Myers and R. W. Sperry has been intensively explored by Japanese psychologists. In

the symposium entitled, "Mechanisms of Discrimination Learning in Animals and Men," K. Hara discussed the interocular transfer of learning that was drastically reduced in forebrain commissurectomized rhesus monkeys.

At the forty-fourth (forty-fifth) annual meeting of the JPA in 1981, discussions on physiological psychology was held in eight (12) sessions with 80 (81) papers. At the forty-fourth annual meeting, these sessions were:

- sleep, wakefulness, meditation, and circadian variations with nine papers,
- lesion and neurological psychology with 13 papers,
- vascular and electrodermal responses with 13 papers,
- functional differences in cerebral hemispheres with seven papers,
- reflex with nine papers,
- cognition and evoked potentials with 13 papers,
- cognition and event-related potentials with seven papers, and
- brain waves with nine papers.

At the forty-fifth annual meeting, twelve sessions were held. They were:

- physiological basis (eight papers),
- conditioning (seven papers),
- feedback (six papers),
- brain waves and evoked potentials (six papers),
- functional differences between left and right hemisphere (six papers),
- lesion studies and administration of drugs (eight papers),
- hippocampus (seven papers),
- event-related evoked potentials (seven papers), and
- somatic responses (five papers).

Sample representations of major research efforts in physiological psychology are described as follows.

K. Fujisawa presented, as continuing efforts in the psychophysiological study of sleep, data on the continuous polygraph recordings of EEGs, eye movements, body movements, respiration rate, and heart rate over a 34-hour period, along with his evaluation of human circadian rhythmicity in many measures derived from brain waves. He used equispectral intensity maps to represent the scalp EEG activities of human subjects. These presentations were his twentieth and twenty-first reports.

T. Hirano described neural mechanisms of classical conditioning by the stimulation of the intracerebral reward area of the rat. In this study, microelectrodes were implanted in the hippocampal CA1 area to record unit activity when classical conditioning was established to a sound stimulus (a conditioned stimulus) paired with microelectrode stimulation of the lateral hypothalamic area (an unconditioned stimulus). He found that the hippocampal area was involved in monitoring reinforcement in a S-S type associative learning.

A. Miyashita and Y. Niimi reported skin potential activity, especially during the period of sleep onset. This report, given at the forty-fourth meeting, the sixth report of an ongoing project at the Tokyo Metropolitan Institute for Neurosciences, related the observation of a rapid decrease in palmar skin potential level from -40 mV during the wakefulness state to around -25 mV as the subjects approached the time of the first sleep spindles.

T. Mino, M. Ohsuga, and Y. Miyata reported on the results of studies on sensory-stimulus habituation. Y. Miyata had been actively studying conditional responses in man for many years (Kotaka and Miyata, 1971). Orienting reflex and its habituation, as a part of mechanisms involved in human conditioned responses as mentioned by I. P. Pavlov, have been studied extensively by Y. Miyata and his group. One of the more familiar papers of Miyata, to American psychologists, has been published in *Psychophysiology* (1975).

K. Matsunaga and his group presented four separate papers describing their study of pupillary movements, hippus, and pupillary dilation association with information processing. M. Sakai and others discussed the reorganization of visual systems after unilateral enucleation in the rat using cerebral-evoked visual potentials. T. Okita and his group, in four papers, presented the results of examining the relation between event-related potentials and human information processing.

A. Katada and others compared the variability of brain wave rms power of sixty mental retardates, ages ranging from 19 to 46 years, with that of ten normal university students. They observed regional differences in the variability of the total power of brain waves between the mental retardates and normals.

K. Miyamoto, who is interested in the research of vocalization mechanisms of mynah birds, observed that under laboratory conditions they could emit imitative vocalizations when a cue was given to them.

S. Kakigi and his group presented four papers at the forty-fourth annual meeting and five papers at the forty-fifth annual meeting on their psychophysiological studies. These papers represent a long-term research program in which 43 papers have already been presented.

The question of laterality (or hemisphericity) was addressed by T. Hatta, using a three-channel projector tachistoscope. Hatta previously observed that an isolated Chinese character (kanji) was processed by the nondominant hemisphere (usually the right hemisphere for the right-handed). He reported in a 1980 paper that the left hemisphere handled the Chinese characters faster than the right if the subjects were asked to process semantic meanings of these characters.

The fascinating contribution to the laterality question by T. Tsunoda of the Tokyo Medical and Dental University was not discussed at the 1980 session. Tsunoda found that the Japanese brain is unique in that its dominant (language) hemisphere processes the vowel sounds, such as /a/, whereas the brains of Westerners handle it in their nondominant hemisphere. At the 1981 annual meeting, K. Tanaka of Kagawa University discussed his prior studies on lateral eye movements when the subjects were asked to locate the source of various sounds when these sounds were transmitted to both ears simultaneously at comparable intensity through headphones. Sounds such as human cries and laughter cause lateral eye movements to the right, whereas sounds of bottles breaking and noises of a passing train cause eyes to move to the left. This finding was interpreted to support Tsunoda's theory about the Japanese brain: the left dominant cerebral hemisphere of the Japanese handles emotional sounds. The lateral eye movements to the right suggested, according to K. Tanaka, a dominance of the left hemisphere. For details of Tsunoda's work, see the ONR Far East *Scientific Bulletin* 9 (1), 111 (1984). The topics of twelve sessions (with 81 papers) at the forty-fifth annual meeting were:

- physiological bases (eight papers) on skin potential level at the time of sleep onset, and other topics,
- reflexes (eight papers), where startle reflexes seen from heart rate acceleration and eye blink response, pupillary responses, and others were discussed,
- conditioning (seven papers),
- biofeedback (six papers), where magnitude estimation of pain with or without increased muscle tension, and electromyographic biofeedback to help the cerebral palsied were discussed,
- cerebral functions (seven papers), where five papers addressed the question of laterality, such as how left or right hemisphere dominance develops in infants, and ear advantage to a consonant-vowel sound or pure tone under dichotic competition,
- evoked potentials (10 papers), where amplitude of visual evoked potentials, and the "Broca-Sulzer effect" of perceived brightness and flash duration were discussed,
- brain waves (two papers), where Fujisawa and his group presented a report on the psychophysiological study of sleep,
- cerebral hemispheric differences (six papers), where laterality was again discussed, for a total of 11 papers at this meeting,
- lesion and drug administration (eight papers),
- hippocampus (seven papers),
- event-related potentials (seven papers), and
- somatic responses (five papers).

#### QUANTITATIVE AND MATHEMATICAL PSYCHOLOGY

##### - Current Studies on Quantitative and Mathematical Psychology

A special section of mathematical psychology has not been set aside at the annual meetings of the JPA; normally mathematical psychologists or psychological statisticians present their papers at other divisions of JPA meetings. Research on mathematical modeling would be presented in the division of sensation/perception. The theory of psychological tests would be reported on in the division of educational psychology.

Quantitative and statistical methods are used in almost all psychological reports and dissertations. Table II shows the current state of quantitative and statistical analyses in Japanese psychological literature.

Among the many kinds of specialization for Japanese psychologists, the specialists in mathematical and statistical psychology have been most active in exchanging ideas, in

teaching, and in doing research at universities and institutes outside of Japan. For example: T. Indow (University of California, Irvine), C. Izawa (Tulane University), S. Nishisato (University of Toronto), Y. Takane (McGill University), and F. Samejima [University of Tennessee; see Samejima (1980)].

At the forty-fifth annual meeting of the JPA, three papers were presented that discussed the question of factorial invariance or the idea of longitudinal factor analysis, using the FACTORMAX and PATTERNMAX methods of confirmatory factor analysis.

## PERSONALITY AND CLINICAL PSYCHOLOGY

### - Current Studies on Personality

Current activities in personality research were described in 71 (62) papers discussed in six (eight) sessions at the forty-fourth (forty-fifth) annual meeting of the JPA.

At the forty-fourth annual meeting, there were six sessions. The first session (11 papers) was concerned with the problems experienced by students in elementary, middle, and high schools. Discussions were held on the environmental conditions contributing to obesity in students, adaptability to school, and the life of high school students as seen from behavior/personality and value systems and parental attitudes towards bringing up children and that relationship to scholastic achievements of middle school students.

The second session (12 papers) dealt with personality and cognition, which discussed:

- ambiguity tolerance,
- the relationship between extraversion-introversion and a higher nervous system type as defined by Nebylitsyn, and
- an evaluation of the effectiveness of the personality type of Rotter's internal-external locus of control in controlling stress.

Stress was created by a task difficulty as well as by compressed air admitted into the right ear canal. Stress response was inferred from an increase in systolic blood pressure and an increased heart rate. The personality factor of the "locus of control" did not predict those who would be better able to cope with stress.

The third session (12 papers) was on morality, values, Zen, and oriental psychology with 13 papers. Discussion was held on the relationship between empathy and resistance to temptation, the mother's value system and factors which determined her value system. The 278th report by Komazawa University on the various aspects of Zen Buddhism represented a long-term effort to achieve total understanding of mental and physical events during Zen practice or Zazen.

The fourth session was on personality tests with 14 papers. Discussions were held on:

- the results of testing the personalities of teams of track athletes at three universities using the Tokyo Personality Inventory (TPI) developed by T. Hidano,
- on the reliability of scoring methods of the Minnesota Multiphasic Personality Inventory (MMPI) and Cattell's P-F Inventory, and the standardization of the Japanese edition of the State-Trait Anxiety Inventory for Children (STAIC),

- and evaluation of the Group Embedded Figures Test (GEFT) as applied to middle school students.

The fifth session was concerned with projective tests such as the Thematic Aperception Test (TAT) and C. Koch's Tree Test. The sixth session (10 papers) dealt with personality, sex difference and behavior, discussion on mental tempo, and on the future tasks of Japanese education in removing sex discrimination.

At the forty-fifth annual meeting, eight sessions were held with 62 paper presentations. These sessions were:

- Zen and meditation (eight papers),
- personality and response bias (eight papers),
- cause attribution and sex role (eight papers),
- behavior/adaptation (eight papers),
- personality during adolescence (eight papers),
- self-image (eight papers),
- anxiety/fear (seven papers), and
- personality tests (seven papers).

#### - Current Activities on Clinical Psychology

At the forty-fourth annual meeting of the JPA, seven sessions were held and a total of 76 papers were presented. These sessions were on:

- Rorschach responses of patients with psychosomatic complaints, schizophrenia, and depressive complaints with 11 papers,
- group psychotherapy in mental hospitals, interview processes with schizophrenic patients, and self-body image of schizophrenic patients,
- psychotherapy, with 14 papers, in which discussions were held on various psychotherapeutic techniques, such as Gestalt therapy, play therapy, group finger painting, Jungian fantasy therapy using clay as a medium for fantasy, and sand play developed by M. Lownfield and transformed by the Japanese as play therapy with a miniature garden in a small box (Hakoniwa),
- counseling and encounter groups, with 11 papers, among which discussions were held on the application of the "focusing technique" proposed by E. T. Gendlin (a University of Chicago psychologist), and case by case experiences of encounter group techniques.

The fifth session discussed various clinical topics, such as:

- intellectual structure of the elderly,
- the elderly's attitudes toward death,
- the psychotherapist's role in treating three terminal cases of progressive muscular dystrophy (Duchenne type),
- educating the nurses on how to "care" rather than to "cure" in some medical cases (especially those with terminally ill patients),



- parental role in reducing fear and anxiety felt by children going through dental treatment,
- impact of dentists' behavior on children as measured by heart rate and blood pressure,
- testing reliability and validity of Spielberger's State-Trait Anxiety Scale by applying it to nursing school students under autogenic training, and also to neurotic or psychosomatic patients at an outpatient clinic, and
- respiration of cerebral palsy patients with speech impediments.

The sixth session was concerned with disorders and maladaptive cases where discussions were held on delayed language development, developmental study of speech and speech guidance for autistic children, psychological traits of enuretic children, the success with play therapy to reduce the number of vomitings of a profoundly retarded child who vomited several times a day for a period of five years.

The seventh session (11 papers) handled the problems of autism (which appears to be on the rise in recent years in Japan) where discussions were held on autism among mental retardates, the role of the mediator in operant conditioning treatment, behavior therapy for autistic children, and development of interpersonal behavior in autistic children.

At the forty-fifth annual meeting, eleven sessions were held with a total of 75 papers. These sessions were on:

- autism (eight papers),
- Rorschach (11 papers), where discussions were held; (a) on Rorschach responses in various esoteric or clinical groups, such as a shaman in Okinawa called "Yuta;" (b) on those responses of older autistic children to see if autism was related to adult schizophrenia; (c) on those epileptics when they were grouped into those who had seizures within two hours after their awakening or those who had seizures during sleep; and (d) on those endogenously depressed,
- psychological tests (eight papers),
- clinical fundamentals (eight papers), where discussions were held on Duchenne type progressive muscular dystrophy patients, children's behavior during dental treatment--the seventh and eighth reports in a continuing series of studies,
- encounter groups (four papers),
- group psychotherapy/psychodrama (10 papers),
- schizophrenia (eight papers),
- mental disorders and family (seven papers),
- language disturbances (eight papers), and
- psychotherapy (14 papers) in two sessions.

## DEVELOPMENTAL AND EDUCATIONAL PSYCHOLOGY

Japanese psychological scientific research was organized so that learning, developmental, and personality psychology would be studied under the umbrella of educational psychology.

### - Current Studies on Developmental Psychology

At the forty-fourth annual meeting of the JPA, 76 papers were presented in seven sessions. These sessions were:

- play of children and perception, with 11 papers,
- recognition, thinking, and conceptualization in children, with 14 papers,
- social behavior in children, with 13 papers,
- adolescence and old age, with seven papers,
- development of interpersonal relations in infants, with seven papers,
- sensory motor developments in infants, with 12 papers, and
- parent-child relationships with 12 papers.

At the forty-fifth annual meeting, seventeen sessions were held to present 132 papers. These sessions were:

- sensation/perception of young infants (eight papers),
- tests for mental and physical development (eight papers),
- cognitive style (eight papers),
- two sessions on behavior of mothers (16 papers),
- parent-child relationships (seven papers),
- adaptation during adolescence (eight papers),
- adaptation of the elderly (eight papers),
- social norms (eight papers),
- concept formation (six papers),
- teaching/learning (seven papers),
- interactions among young infants (six papers),
- parent-child relations and parental image (six papers),
- speech (seven papers),
- early language (six papers),
- self-consciousness (eight papers), and
- adjustment of behavior (seven papers).

As previously mentioned, many differing views exist in defining the scope of educational psychology. An analysis of the classification of oral presentations from the first annual meeting held in 1959 by the Japanese Association of Educational Psychology to its seventeenth annual meeting in 1975 revealed that the greatest number of paper presentations consisted of topics on developmental psychology; then teaching/learning; clinical topics of mental/physical disorders; personality; human relations/educational environments; and measurement/evaluation in decreasing numerical order.

A post-WW II trend in educational psychology could be discerned in three symposia held in 1955, 1964, and 1967; all sponsored by the Japanese Association of Educational Psychology.

The 1955 symposium, held at Nagoya University, on "The Way Educational Psychology Should Be" and on "Methodology of Educational Psychology" had discussions

by A. Tsuzuki, A. Yoda, T. Masaki, M. Kido, S. Onishi, Y. Shioda, T. Konoda, and F. Marui. A. Tsuzuki summarized the conclusion of the symposia as follows:

- the image of human subjects in educational research differs considerably, depending on whether emphasis is placed on the theoretical or the practical aspects of educational psychology,
- if educational psychology is to contribute to practical teaching processes in schools, it would be forced to choose educational goals and ideals on which the socio-economic-political structure of our society would have a great deal of influence,
- attitudes of the educational psychologists towards research in education are important as they determine not only their relationship with other education-related scientific disciplines, but also the manner in which they develop their own research methodology.

In the 1964 symposium at the meeting of the Japanese Society of Educational Psychology, "Educational Principles and Psychology" and "Educating Children, Family Education, and Psychology" were discussed. The prime task of educational psychology was said to establish an ideal image of what children should be, and for which realization all educators should strive. In the discussions on "Student Guidance and Psychology" and "Social Education, Problems in Adolescence, and Psychology," the paucity of research on student guidance was apparent.

In the 1967 symposium, participants expressed an urgent need for integrating the theory and the practice of educational psychology as it pertains to the population of children/adolescents. They requested that research methods be structured "from the view point of educational evaluation and educational learning psychology." Furthermore, the participants pointed out the importance of keeping close relationships between teachers and researchers in educational psychology to provide a better understanding of student guidance and special education.

These symposia revealed the persistent trend that the tasks of educational psychology are increasingly moving towards the eradication of problems in educational situations. This trend suggests, at the same time, that basic problems in educational psychology have not changed in the 40 years since the end of World War II.

#### - Current Studies on Special Education

The forty-fourth annual meeting of the JPA had three sessions (21 papers) on special education. These sessions discussed:

- mental retardates with seven papers,
- handicapped children and their parents with seven papers, and
- autism and the emotionally disturbed, with seven papers.

Recently, G. Naruse and his group at Kyushu University achieved considerable advancement in training children with cerebral palsy to move their bodies and limbs. In the past, the methods used for patient rehabilitation was in the domain of physicians. Naruse adopted a psychological approach in rehabilitation methods. His work was reported on in the movements section of the forty-fourth annual meeting of the JPA.

Currently, basic research is conducted on the visually or aurally handicapped and mental retardates using brain waves and evoked potentials. The research areas which should be and, it is hoped, will be pushed are the detailed developmental study of children from birth to about seven years of age, and the problems of teaching basic skills to profoundly multiple-handicapped children.

At the forty-fifth annual meeting, two sessions were held with 16 papers. These two sessions dealt with handicapped children, and discussions were held on the movement disorders of children with cerebral palsy, severely retarded children, autistic children, children with muscular dystrophy, the aurally handicapped child, and the stress which parents of physically and mentally handicapped children experience.

## SOCIAL PSYCHOLOGY

### - Current Studies on Social Psychology

Social psychological studies at the forty-fourth annual meeting of the JPA were presented in eight sessions with 75 papers. The first session (11 papers) dealt with social motives and interpersonal cognition where discussions were held on the experimental studies of the "personal constructs theory" proposed by Crockett and Meisel (1974), and on the measurement of feelings towards others by changes in personal space or the Body Buffer Zone (BBZ) proposed by E. T. Hall. The second session (10 papers) was on interpersonal behavior.

The third session (13 papers) was concerned with regionality and environment where factors contributing to a better habitability were discussed. Kwansel Gakuin University's study evaluated the relationship of regional life information (regional shopping news, addresses of nearby medical facilities, movies, and other information used daily, and all provided by government-sponsored experimental cable TV operation) on habitability. Tokyo Metropolitan University's study examined psychological characteristics of the inhabitants who had been living in a mass (high density) housing complex.

The fourth session (11 papers) involved attitudes and their modifications. The fifth session (seven papers) included problems on social maladaptation and social awareness where discussions were held on social escape behavior among young adults.

The sixth session (seven papers) dealt with self-models, where evaluation of modern youths' self-image and the objective study of self-awareness were discussed. In the seventh session entitled "Panic," four papers reported the results of concurrently conducted experiments at Osaka University and Kumamoto University, both using the same experimental arrangements, to produce simulated panic situations in groups of subjects. Subjects were required to escape from instrumented booths within 30 seconds by pressing response buttons, but only one subject at one time. With the threat of electrical shock and "jamming," the experimental situation approximated a panic situation such as found in natural disasters. This study was closely related to H. H. Kelly's examination of the dynamics of escape behavior during a simulated catastrophic event.

The eighth session was on group/collective movements with 12 papers, with discussions held on the differences between the Japanese and Americans in distributive

justice within a group, on the mathematical model of group-size as pedestrians, and on attitudinal differences between Japanese and American leaders in international relations.

At the forty-fifth annual meeting, the division of social psychology had 11 sessions with 70 papers. These 11 sessions were:

- cross-cultural research (eight papers),
- territoriality/environment (eight papers), where discussions continued from the previous annual meeting in 1980 on habitability and psychology in a mass housing complex,
- self-consciousness (seven papers),
- game model (six papers),
- group behavior (six papers),
- interpersonal recognition (seven papers),
- attitudes and their modifications (eight papers),
- two sessions on interpersonal behavior (15 papers),
- social behavior during disasters (eight papers), and
- panic (seven papers).

#### INDUSTRIAL PSYCHOLOGY

##### - Current Studies on Industrial Psychology

At the forty-fourth annual meeting, four sessions were provided for industrial psychology, and 36 papers were presented. The first session (nine papers) discussed drives, organization, and leadership, where discussions were held on adaptation to work environment, characteristics of an air traffic controller's job, and questions of the growth of personality through work and leisure. The second session (10 papers) was concerned with work-related movements of body and physical and mental capabilities where discussions were held on aging-related changes in psychological functions, and a self-report symptoms checklist of fatigue.

The third session (seven papers) dealt with accidents and traffic behavior, where discussions were held on:

- the manner of acquisition of visual information during driving,
- (traffic) gap acceptance shown by pedestrians in their decision whether they should walk across or not across the street against a heavy traffic flow,
- a relationship between accident rate and level of intelligence, and
- accident proneness as evaluated by manner of controlling driving speed control.

The fourth session (seven papers) was on mental health problems in business enterprises where discussions were held on diagnostic systems for mental health in a business organization. The other three papers reported on the selection of a supervisor/technical staff by means of a multifaceted evaluation system.

At the forty-fifth annual meeting, five sessions were held with 38 paper presentations. These sessions were on:

- work efficiency in two sessions (15 papers),
- behavior in accident and traffic cases (eight papers),

- occupational consciousness and occupational adaptation (eight papers), and
- mental health management in private business enterprises (seven papers).

The current concern of Japanese industrial psychologists deserves the careful attention of American industrial psychologists. They seem to be focusing on the global problems of mental health within business and industrial organizations. Japanese industrial psychologists appear to be facing new challenges and are being forced to reexamine the influence of, and their dependence on, the American way of thinking which is prevalent in current Japanese industrial psychology. Japanese industrial psychologists' successes in the past have been because of European and American psychological techniques. However, recently in Japan, industrial psychologists have had to resolve new problems, along with their American and European counterparts, on the problem of "human isolation" which has been felt acutely by the Japanese worker as a result of the rapid incorporation of "high technology." Japanese industrial psychologists are facing the formidable task of resolving the question of how to conserve "humanity" in an increasingly impersonal work environment.

TABLE I

PERCENTAGE OF PAPERS IN DIVISIONS\*  
AT THE JPA ANNUAL CONVENTION

Year Location	1970 Hokkaido		1980 Sendai	1981 Tokyo
Theories and Method	4.0	Method/Measurement General/Principles	3.0	2.9
Physiological	6.0	Physiology/EEG,EP Emotion/Feeling	11.6	11.6
Sensation and Perception	15.0	Sensation and Perception	12.7	11.7
Behavior and Behavior Theory	5.0	Language/Cognition Motivation/Thinking Instinct/Hereditry	11.7	11.2
Developmental	11.0	Developmental	9.3	15.2
Learning and Memory	14.0	Learning/Memory	10.9	12.1
Educational	8.0	Special Education/Motion Education	6.8	3.5
Personality	7.0	Personality	9.2	7.6
Clinical	9.0	Clinical	9.7	10.1
Criminal	2.0	Criminal	0.8	0.7
Social	10.0	Social	9.6	8.6
Industrial	9.0	Industrial	4.6	4.6
Total # of papers	588		779	818

\* Source: Y. Tanaka and G. W. Englund, *Annual Review of Psychology*, 23, Table II, 698 (1972).

TABLE II

Utilization of quantitative and mathematical methods in papers presented at 1968 and 1969 annual meetings of the JPA and papers published in the *Japanese Journal of Psychology* (JJP) and *Japanese Psychological Research* (JPR).

	1968 Annual Meeting	1969 Annual Meeting	1968-1970		1971-1977	
			JJP	JPR	JJP	JPR
No data (theoretical, etc.)	32	43	4	6		
Data analysis required	445*	326	42	34		
Tables/Frequency counts/Rate	413	304	39	38		
Sign test	2	1	2	0		
Binomial test	0	1	1	0		
H test	2	0	1	2		
U test	7	5	2	3		
Friedman's test	1	0	1	0		
Smirnov's test	0	0	1	0		
Phi coefficient	0	2	0	0		
Chi-squared	26	23	9	2		
t test	69	68	11	11		
ANOVA	63	49	24	19		
Correlation	41	33	5	3		
Rank order correlation	8	2	3	0		
Least squares	1	1	0	0		
Trend analysis	0	1	0	2		
Factor analyses	31	17	8	3	22	11
Multivariate analysis	0	1	0	0	0	0
Paired comparison	1	0	0	0	1	1
MDS	2	0	0	3	0	1
Semantic differential	1	0	2	0	6	3
Information quanta	1	0	2	1	1	2
Fourier analysis	2	1	0	0	2	0
Bayes' probability	0	0	1	0	0	0
Fitting math model	0	0	2	2	6	8

\* The numbers in this table represent all of the statistical tests used in the papers.

\*\* Source: *Trends in Modern Psychology, 1946-1980*. Edited by T. Hidano, Kawashima-shoten, Tokyo 1980.



## APPENDIX I

### SYMPOSIA AND LECTURES HELD IN JAPAN

Partial translation of the list given in *Trends in Modern Psychology*.  
Abbreviations in the parenthesis represent the name of the sponsoring organization.

- (JPA) = Japanese Psychological Association  
(AP) = Japan Association of Applied Psychology  
(EP) = Japan Association of Educational Psychology  
(GD) = Japanese Group Dynamics Association  
(SP) = Japanese Society of Social Psychology  
(JSAP) = Japanese Society of Animal Psychology  
(SE) = Japanese Society of Special Education

YEAR	SYMPOSIUM (=S) and LECTURE (=L)
1978	
S	The examination of basic assumptions prior to conducting experiments (JPA)
S	The theoretical development of interpersonal behavior and its various problems (JPA)
S	Methodology on developmental psychology (JPA)
S	Today's problems in research on industrial fatigue (JPA)
S	Problems of input/output in long-term memory (JPA)
S	Physiological indicators of mental phenomena (JPA)
S	Qualification problems of clinical psychologists (JPA)
S	Cognition of environment in human environment systems (JPA)
S	Guidance for the handicapped child (JPA)
S	Basic problems of community psychology (JPA)
S	Behaviorism and phenomenology in psychology (JPA)
S	Current state of humanistic psychology in our country and its future tasks (JPA)
S	Laterality (JPA)
S	When the problem child becomes an adolescent (JPA)
S	Various processes of personality, cross-cultural research, and their research methods (JPA)
S	Case studies in psychological clinics (JPA)
S	Today's tasks in family relations (AP)
S	Today's image of university students and university education (AP)
S	(A) Twenty-year history and perspectives of the Japanese Association of Educational Psychology (EP)
	(B) Educational psychology as seen from a teaching setting (EP)
S	Cognitive socialization (EP)
S	How will the family change in the society of the future? (SP)
S	Stopping crime by social punishment (CP)
S	Current state of prediction of (repeated) delinquent behavior and various problems (CP)
S	The obligation in schooling for nursing/rehabilitation (SE)

\*See references

- S Development and education of severely/multiple-handicapped children (SE)
- S Again, concern with Rorschach (SP)
- S What is psychodiagnostics? (SP)
- S Questioning of developmental guarantees (SP)
- S Problems of delinquency and actual education (SP)
- L Retrospect and perspective of rehabilitation psychology (JPA)
- L Experiential process therapy (JPA)
- L The problems of today's private small teaching schools (JPA)
- L Evolutionary development of animals as seen from ethology and the problem of aging (JSAP)
- L Problems of educational psychology and its methodology (EP)
- L Current state of educational psychology in West Germany (EP)
- L Various problems of criminalization and decriminalization (CP)
- L My Nakajikiri (SP)

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1979

- S Expectations for mathematical psychology (JPA)
- S Animal learning and human learning (JPA)
- S Time adjustment mechanisms in behavior (JPA)
- S Various problems of visual movement perception (JPA)
- S Morality and socialization ((JPA)
- S Prognosis of psychotherapy (JPA)
- S Cross-cultural twists in international communication (JPA)
- S Organization in business management and personnel problems (JPA)
- S How should education be for a psychology major? (JPA)
- S Role of the computer in education/practicum--current status and its future (AP)
- S Aging and problems of industry (AP)
- S Educational psychology in training aesthetic sentiments (EP)
- S Practical teaching and educational psychology (EP)
- S On humanity (EP)
- S Independent symposium (EP)
  - Learning disabilities
  - Developmental study and present society
  - Utilization of computers in educational research
  - Educational functions of school counseling
- S Juvenile delinquents
- S The feasibility of applying Montessori educational methods in the training of the handicapped (SE)
- S Qualifications of training/therapist for the sensory language disturbed
- L Selection by consequences (JPA)
- L Problems of abnormal behavior among today's children (AP)
- L Behavioral study and animal experimentations (JSAP)
- L Cases of retarded development due to poverty of early environment (EP)
- L Changing society and problems with young adults (SP)

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1980 (All presented at the annual meeting of the JPA)

- L Behavior and neuronal activities
- L Self in Self-emotive

- L A historical perspective in research on child development
- L Consideration on understanding by empathy and its process of information processing
- L Various aspects of hierarchical organization and mutual cooperation in Japanese monkeys
- L Human traits in discriminative information processing of patterns in letters
- L Egalitarianism and other directedness in Japanese as seen in distributive justice
- L Reinforcement types and modifications of social behavior
- L Expectation of group achievements
- L Perception and language
- L Present status and tasks of study on cross-cultural cognitive developments

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1981 (All presented at the annual meeting of the JPA)

- S Mini and microcomputers and psychological experiments
- S Information processing of patterns/language
- S Development of symbolic functions in infants
- S Bilingualism and biculturalism
- S Present status and future of environmental psychology
- S Various problems of humanistic psychology
- S Care and development of handicapped children
- S Various issues surrounding qualification standards of clinical psychologists
- S Problems of self-consciousness
- S Developmental psychology and ethology
- S Psychophysiology of consciousness
- S New waves in the study of cognitive development
- S Comparison as a method
- S Perception/cognition function and its development and its disorders
- S Perspectives of study of emotions
- S Various problems of achievement motives
- S Various phases of study on the very elderly
- S Various problems of personality development to adolescence
- S Individual differences and individual traits
- S Present status and perspective of family clinical psychology
- L Asymmetry of cerebral hemisphere functions and disordered cerebral differentiation
- L Processing unit of visual perceptual system and processing cycle
- L Analysis of operant learning in field groups of Japanese monkeys
- L Concept of success-avoidance and issues
- L Psychological effort and memory
- L Study of depth perception by the visual pitfall technique
- L Learning of mentally retarded children and adults
- L Consideration of social influences over cognitive development
- L Inhibitive power of social sanctions over delinquency
- L Reward distribution and its effect in group organizations
- L Measurement and diagnosis of ego functions

## APPENDIX II

### PSYCHOLOGICAL ASSOCIATIONS AND SOCIETIES

#### - Japanese Psychological Association

The Japanese Psychological Association (JPA) has five divisions. They are:

Division I	Physiological Psychology, Perception Cognition, Learning, and Thinking
Division II	Developmental Psychology, Educational Psychology
Division III	Clinical Psychology, Personality, Criminal Psychology
Division IV	Social Psychology, Industrial Psychology
Division V	Method, Theory, and History

Address 802, Bunkyo Center Building  
4-37-13, Hongo, Bunkyo-ku, Tokyo 113

Telephone (03) 814-3953

Founded in 1927

Number of full members 3,964

#### Publications

*The Japanese Journal of Psychology*  
(bimonthly, in Japanese with English abstracts, since 1926, one volume per year, about 360 pages per volume.)

*Japanese Psychological Research*  
(quarterly, in English, since 1954, one volume per year, about 200 pages per volume.)

*Psychological Monographs*  
(irregularly as required, in Japanese with English abstracts.)

#### - Japan Association of Applied Psychology

Address c/o Counseling Center, Keio University  
Mita, Minato-ku, Tokyo 108

Telephone (03) 453-4511

Founded in 1931

Number of full members 987

#### Publications

*The Japanese Journal of Applied Psychology*  
(semiannual, in Japanese.)

*Psychology Lectures*  
(in 12 volumes, since 1954, in Japanese.)

*Handbook of Industrial Psychology*  
(1958, in Japanese.)

- Japanese Society of Animal Psychology

Address c/o Department of Psychology, Faculty of Letters,  
University of Tokyo  
Hongo, Bunkyo-ku, Tokyo 113

Telephone (03) 812-2111, Ext. 3861

Founded in 1933

Number of full members 440

Publications

*The Annual of Animal Psychology*  
(either in English or Japanese with English abstracts.)

- Japanese Group Dynamics Association

Address c/o Japan Institute for Group Dynamics,  
Nishinippon Shimbun Kaikan,  
11-4-1 Tenji, Chuo-ku, Fukuoka 810

Founded in 1949

Number of full members 496

Publications

*The Japanese Journal of Experimental Social Psychology*  
(semiannual, in Japanese with English abstracts, since 1971.)

*Group Dynamics in Japan*  
(edited by J. Misumi, 1973, in Japanese, and also in English.)

- Japanese Association of Educational Psychology

Address c/o Faculty of Education,  
University of Tokyo  
7-3-1 Hongo, Bunkyo-ku, Tokyo 113

Telephone (03) 812-2111, Ext. 3951

Founded in 1959

Number of full members 2,830

## Publications

*Japanese Journal of Educational Psychology*  
(quarterly, in Japanese with English abstracts, since 1953.)

*The Annual Report of Educational Psychology in Japan*  
(in Japanese with English abstracts, since 1961.)

### - Japan Society of Social Psychology

Address c/o Department of Psychology,  
Tokyo Institute of Technology  
2-12-2 Ookayama, Meguro-ku, Tokyo 152

Telephone (03) 726-1111, Ext. 2262

Founded in 1960

Number of full members 640

#### Publications

*The Japanese Annals of Social Psychology*  
(in Japanese, since 1960.)

*Bulletin of the Japan Society of Social Psychology*  
(quarterly, in Japanese.)

*Index of Published Works by the Members of the Japan Society of Social Psychology*  
(one volume published in 1977 to cover the period from Jan 1973 to Dec 1976; another volume published in 1979 to cover the period from Jan 1977 to March 1979.)

### - Japanese Association of Criminal Psychology

Address c/o Tokyo Juvenile Detention and Classification Home  
2-11-7 Hikawadai, Nerima-ku, Tokyo 176

Telephone (03) 931-1141

Founded in 1963

Number of full members 696

#### Publications

*Japanese Journal of Criminal Psychology*  
(semiannual, in Japanese with English abstracts, since 1963.)

*Catalog of Domestic and Foreign Literature on Development-Maturation and Delinquency*  
(published in 1973.)

- Japan Association of Special Education

Address c/o Mentally and Physically Handicapped Study Section,  
Tsukuba University  
1-1-1 Tennodai, Sakuramura, Shinji-gun, Ibaraki-ken 305

Telephone 0298-53-4557

Founded in 1963

Number of full members 1,979

Publications

*The Journal of Special Educational Research*  
(quarterly, since 1964, in Japanese.)

- Japanese Clinical Psychological Association

Address c/o National Institute of Health  
1-7-3 Konodai, Ichikawa-shi, Chiba 272

Telephone 0473-72-0141

Founded in 1964

Number of full members 895

Publications

*Japanese Journal of Clinical Psychology*  
(quarterly, in Japanese.)

*The Clinical Psychologist* (Newsletter)  
(bimonthly, in Japanese.)

- Japanese Biofeedback Research Society

Address c/o Department of Psychology, Sophia University  
Kioi-cho, Chiyoda-ku, Tokyo 102

Telephone (03) 238-3815

Founded in 1972

Number of full members 180

Publications

*Biofeedback Research*  
(annual, in Japanese with English abstracts.)

- Japanese Society for Physiological Psychology and Psychophysiology

Address c/o Department of Psychology, Faculty of Literature, Sophia University  
Kioi-cho, Chiyoda-ku, Tokyo 102

Telephone (03) 238-3811

Founded in 1960

Number of full members 120

- Society of Learning Theory Advanced for Personality and Behavior Disorder (PBD Society)

Address c/o Department of Psychology, School of Letters, Waseda University  
Toyama-cho, Shinjuku-ku, Tokyo 160

Telephone (03) 203-4111, Ext. 501, 301

Founded in 1960

Number of full members 172

Publications

*PBD Society Report*  
(annual, in Japanese.)



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# INTERNATIONAL MEETINGS AND EXHIBITIONS IN THE FAR EAST

1984-1986

Compiled by Seikoh Sakiyama

The Australian Academy of Science, the Japan Convention Bureau, and the Science Council of Japan are the primary sources for this list. Readers are asked to notify us of any upcoming international meetings and exhibitions in the Far East which have not yet been included in this report.

1984

Date	Title	Site	For Information, contact
October 1-6	The 3rd Asian Pacific Regional Astronomy Meeting of IAU	Tokyo, Japan	Professor T. Kogure Department of Astronomy Faculty of Science University of Kyoto Sakyo-ku, Kyoto 606
October 1-7	Pacific Region Wood Anatomy Conference	Tsukuba, Japan	P.O. Box 16 Tsukuba Agricultural and Forestry Research Insti- tutes Ibaraki 305
October 2-4	Software Show '84	Tokyo, Japan	Japan Software Industry Association Kikai Shinko Kaikan 3-5-8, Shiba-Koen Minato-ku, Tokyo 105
October 3-6	The 11th Measuring Instruments Exhibition	Tokyo, Japan	Japan Measuring Instruments Federation 25-1, Nandocho Shinjuku-ku, Tokyo 162
October 3-6	International Seminar on Information Systems for Urban and Regional Planning	Kawasaki, Japan	Planning Section Kawasaki-city Office 1, Miyamoto-cho Kawasaki-ku, Kawasaki Kanagawa 210
October 3-6	'84 Osaka International Environment Preserving Machinery and Equipment Exhibition	Osaka, Japan	The Nihon Kogyo Shimbun Company, Ltd. 2-4-9, Umeda Kita-ku, Osaka 530
	'84 Resources Recycling Technology and Energy Saving Instrument Exhibition		

# 1984 Continued

Date	Title	Site	For Information, contact
	'84 Osaka Physical Distribution and Materials Handling Exhibition		
	'84 Robot and Automation Equipment Fair		
October 4-8	1984 Japan Machinery Fair	Nagoya, Japan	Nagoya-shi Mihon-ichi Kyokai 2-6-3, Fukiage Chikusa-ku, Nagoya 464
October 4-9	'84 Japan Electronics Show	Tokyo, Japan	Japan Electronics Show Association c/o Tokyo Chamber of Commerce and Industry 3-2-2, Marunouchi Chiyoda-ku, Tokyo 100
October 6-9	The 5th General Meeting of Japanese Biochemical Society	Tokyo, Japan	Professor S. Nojima Faculty of Pharmacology University of Tokyo 7-3-1, Hongo Bunkyo-ku, Tokyo 112
October 7-12	The XVIIth International Congress of Internal Medicine	Kyoto, Japan	The Japan Society of Internal Medicine Hongo Daiichi Building, 8F 3-34-3, Hongo Bunkyo-ku, Tokyo 113
October 9-11	Meeting of Iron and Steel Institute of Japan	Hiroshima, Japan	Editorial Section, ISIJ Keidanren Kaikan 3F 1-9-4, Ohtemachi Chiyoda-ku, Tokyo 100
October 14-20	Conference on Mineral Processing and Extractive Metallurgy	Kunming, People's Republic of China	Nie Zhong Yong, Director Chinese Academy of Sciences Scientific and Technical Information Institute Beijing
October 15-19	Powder Industry '84 Exhibition	Tokyo, Japan	Powder Industry Office Nihon Noritsu Kyokai 3-1-22, Shiba-Koen Minato-ku, Tokyo 105

# 1984 Continued

Date	Title	Site	For Information, contact
October 16-18	1984 International Symposium on Electromagnetic Compatibility (EMC)	Tokyo, Japan	Professor T. Takagi Department of Electrical Communications Faculty of Engineering Tohoku University Sendai, Miyagi 980
October 17-18	NRDO Conference 1984 (National Research Development Organization)	Kyoto, Japan	New Technology Development Organization 2-5-2, Nagata-cho Chiyoda-ku, Tokyo 100
October 22-26	The 9th International Conference on Infrared and Millimeter Waves	Takarazuka, Japan	Dr. H. Yoshinaga Department of Applied Physics Osaka University Yamadaoka, Suita Osaka 565
October 22-26	The 10th Annual International Conference on Industrial Electronics, Control and Instrumentation (IECON '84)	Tokyo, Japan	Professor H. Hanada IEEE-IES Electrical Engineering Department Kobe University Nada-ku, Kobe 657
October 23-25	1984 Fall Meeting of Atomic Energy Society of Japan	Tokai-maru, Japan	Atomic Energy Society of Japan (AESJ) 1-1-13, Shimbashi Minato-ku, Tokyo 105
October 28-31	U.S.-Japan Workshop on Risk Management	Tsukuba, Japan	Professor Noboru Sakashita University of Tsukuba 1-1-1, Tennodai Sakura-mura Niihari-gun, Ibaraki 300-31
October 30-November 2	The 7th International Conference on Computer Communication (ICCC '84)	Sydney, Australia	Dr. R. Cook Overseas Telecommunications 32-36 Marine Place Sydney, N.S.W. 2000
October 30-November 1	1984 Transport Conference Bulk Transport; Solid Liquid, or Gas	Perth, Australia	Conference Department The Institute of Engineers, Australia 11 National Court Barton, A.C.T. 2600

# 1984 Continued

Date	Title	Site	For Information, contact
October 30- November 2	'84 Optoelectronic Industry and Technology Exhibition	Tokyo, Japan	The Nihon Kogyo Shimbun Company, Ltd. 1-7-2, Ohtemachi Chiyoda-ku, Tokyo 100
October 30- November 8	The 12th Japan Inter- national Machine Tool Fair	Tokyo, Japan	Osaka International Trade Fair Commission c/o International Hotel 58, Hashizume-cho Uchi-Hommachi Higashi-ku, Osaka 540
October (tentative)	Institute of Engineers Electric Energy Conference	Perth, Australia	Dr. J. Sullivan Science House 712 Murray Street Perth, W.A. 6000
October (tentative)	International Association of Seismology and Physics of the Earth's Interior (IASPEI) Regional Assembly	Hyderabad, India	IASPEI Regional Assembly Office National Geophysical Research Institute Hyderabad 500, 007
November 1-5	Workshop on Neuroscience	Baroda, India	Dr. S. Radhakrishna COSTED Secretary Indian Institute of Science Bangalore 560012
November 5-8	Fourth Annual Meeting of the Bioelectrical Repair and Growth Society (BRAGS)	Kyoto, Japan	Dr. Shiro Inoue Murakami Memorial Hospital Gifu Dental University 1-6, Wakamiya-cho Gifu 500
November 12-15	The Second International Conference on Electro- static Precipitation	Kyoto, Japan	Professor Senichi Masuda Chairman, The Institute of Electrostatics Japan Sharumu 80 Building, 4F 4-1-3, Hongo Bunkyo-ku, Tokyo 113
November 13-15	Microsystem Show '84	Tokyo, Japan	Japan Microphotography Association Daini Okochi Building 1-9-15, Kajicho Chiyoda-ku, Tokyo 101

1984 Continued

Date	Title	Site	For Information, contact
November 13-16	The 1st International Photovoltaic Science and Engineering Conference	Kobe, Japan	Professor Taneo Nishino Faculty of Engineering Science Osaka University 1-1, Machikaneyama-cho Toyonaka, Osaka 560
November 13-16	The 23rd Analytical Instruments Show	Tokyo, Japan	Japan Analytical Instru- ments Manufacturers Taimei Building 3-22, Kanda-Ogawa-cho Chiyoda-ku, Tokyo 100
November 14-16	The 19th Exhibition and Conference of New Electrical Insulating Materials	Tokyo, Japan	Japan Electrical Insula- tion Materials Association Iwao Building 1-16-2, Toranomon Minato-ku, Tokyo 105
November 18-22	Structure, Biogenesis, and Transport Properties of Biomembranes	Madurai, India	International Union of Biochemistry
November 19-22	The 7th International Hospital Engineering Exhibition (Hospex Japan '84)	Tokyo, Japan	Japan Management Association Kyoritsu Building 3-1-22, Shiba-Koen Minato-ku, Tokyo 105
November 19-23	The 12th World Mining Congress	New Delhi, India	Organizing Secretary 12th World Mining Congress The Institution of Engineers, India 8 Gokhale Road Calcutta 700020
November 20-22	The 12th NECA Technical Fair	Tokyo, Japan	Nihon Electric Control Equipment Industry Association Daimon Hikari Building 2-1-18, Hamamatsucho Minato-ku, Tokyo 150

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Date	Title	Site	For Information, contact
November 20-22	AIM International Conference on Advances in Manufacturing (Held in conjunction with Metalasia 84 and Automasia 84)	Singapore	Conference Director AIM-IFS Conference 35-39 High Street Kempston Bedford MK2 7BT U.K.
November 21-22	'84 Japan Education Materials Exhibition	Tokyo, Japan	Japan Association of Manufacturers and Distributors of Educational Materials 1-17-1, Toranomon Minato-ku, Tokyo 105
November 21-28	International Mining Machinery Exhibition (Held in association with 12th World Mining Congress)	New Delhi, India	Mining, Geological and Metallurgical Institute of India 29 Jawaharlal Nehru Road Calcutta 700016
November 22-23	Technology: Past, Present, and Future	Melbourne, Australia	Executive Officer Australian Academy of Technological Sciences Clunies Ross House 191 Royal Parade Parkville, Victoria 3052
November 25-28	Kyoto Conference of Prostaglandins	Kyoto, Japan	KCP Office Medical School Tokushima University Kuramoto-cho, Tokushima Tokushima 770
November 26-30	Scientific Committee on Solar-Terrestrial Physics and Committee on Space Research, International Map Symposium	Kyoto, Japan	Professor S. Kato Kyoto University Yoshida-honcho Sakyo-ku, Kyoto 606
November (tentative)	International Union of Pure and Applied Chemistry, The 7th International Biotech- nology Symposium	New Delhi, India	Dr. M. Williams Bank Court Chambers 2-3 Pound Way Cowley Center Oxford OX4 3YF U.K.



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Date	Title	Site	For Information, contact
December 3-5	Semicon Japan '84 (Semiconductors)	Tokyo, Japan	Secretariat, Semicon Japan '83 c/o Marcom International Inc. Akasaka-Omotemachi Building, Rm 705 4-8029, Akasaka Minato-ku, Tokyo 107
December 4-10	The 6th International Conference on Fracture (Material)	New Delhi, India	Dr. Raju Deputy Director National Aeronautical Laboratory Bangalore 560017
December	The 40th Annual Session of the Sri Lanka Association for the Advancement of Science	Colombo, Sri Lanka	Dr. T. Gunawardhane 120/10 Wijierama Mawatha Colombo 7
Undecided	International Association of Hydrological Science on Groundwater	Undecided, Australia	Dr. J. C. Rodda Water Data Unit Reading Bridge House Reading RG1 8PS U.K.
Undecided	The 3rd Asia and Oceania Conference of Nuclear Medicine	Seoul, Korea	Korean Society of Nuclear Medicine 28 Ueong-dong Chongo-ku, Seoul
Undecided	Asian-Australian Association of Animal Production/Animal Science Societies	Seoul, Korea	Department of Animal Science College of Agriculture Seoul National University 103 Seodon-dong Suwon City, (Konggi)
Undecided	International Federation of Society for Electron Microscopy Asian Pacific Electron Microscopy Congress	Singapore	Department of Material Science and Engineering 280 Hearst Mining Building Berkeley, CA 94720 U.S.A.

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Date	Title	Site	For Information, contact
January 14-15	Automation Asia '85 Instrument Society of America and Society of Manufacturing Engineers Floating Exhibition	Seoul, South Korea	Exhibits Development Manager, SME 1 SME Drive P.O. Box 930 Dearborn MI 48121 U.S.A
February 3-7	The 5th International Congress: Transporta- tion	Baguio City, Philippines	PCOC, 2F, Proyal Bay Terrace United Nations Avenues Ermita P.O. Box 4486 Metro Manila
February 11-14	Polymer 85: Characteri- zation and Analysis of Polymers, International Polymer Symposium	Melbourne, Australia	Polymer 85, Royal Australian Chemical Institute 191 Royal Parade Parkville, Victoria 3052
February 11-16	The 2nd Asian Mining Conference and Exhibition (Rescheduled from 5-8 November 1984)	Manila, Philippines	Conference Office Institution of Mining and Metallurgy 44 Portland Place London WIN 4BR U.K.
February (tentative)	The 5th International Congress of Pacific Science Association	Bakguio, Philippines	Dr. Paulo Campos National Research Council of the Philippines Gen Santos Avenue Bicutan, Taguig Metro Manila
February (tentative)	Carbon Transport in Major World Rivers	Tianjin, China	Dr. V. Smirnyagin 51 Building de Montmorency 75016 Paris
March (tentative)	Annual National Confer- ence of the Institution of Engineers, Australia	Melbourne, Australia	LtCol. J.A. McDonald Secretary, Victoria Division Institute of Engineers, Australia National Science Center 191 Royal Parade Parkville, Victoria 3052

# 1985 Continued

Date	Title	Site	For Information, contact
April 2-6	Wire Tokyo 85: The 2nd International Wire Exhibition	Tokyo, Japan	Dr. Frank Hodgson Director of Public Relations Mack-Brooks Exhibitions 62 Victoria Street St. Albans AL1 3XT U.K.
April 15-19	Eighth Australian Symposium on Analytical Chemistry	Melbourne, Australia	Eighth ASAC G.P.O. Box 1929 Canberra, A.C.T. 2601
May 11-16	The 13th Congress of the Council of Mining and Metallurgical Institutions	Canberra, Australia	Council of Mining and Metallurgical Insti- tutions 44 Portland Place London W1N 4BR U.K.
May 14-16	1985 Symposium on VLSI Technology	Shima, Japan	Professor Shoji Tanaka Faculty of Engineering University of Tokyo 7-3-1, Hongo Bunkyo-ku, Tokyo 112
May 20-24	The 3rd Conference on Steel Development	Melbourne, Australia	Australian Institute of Steel Construction P.O. Box 434 Milsons Point, N.S.W. 2061
June 5-7	1985 International Symposium on Circuits and Systems	Kyoto, Japan	Professor Shoji Shinoda Faculty of Engineering Science Chuo University 1-13-27 Kasuga Bunkyo-ku, Tokyo 112
July 14-20	The 6th International Congress for Ultrasound in Medicine and Biology	Sydney, Australia	Dr. R. Jellins P.O. Box R374 Royal Exchange Sydney, N.S.W. 2000
August 6-8	ISGF 85: The 4th Inter- national Symposium	Sapporo, Japan	ISGF 85, Institute of Low Temperature Science Hokkaido University Sapporo, Hokkaido 060

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Date	Title	Site	For Information, contact
August 12-16	The 6th International Meeting on Ferro-electricity	Kobe, Japan	Professor S. Nomura Physical Electronics Faculty of Engineering Tokyo Institute of Technology Meguro-ku, Tokyo 152
August 18-23	The 8th International Conference on Chemical Education	Tokyo, Japan	The Chemical Society of Japan 1-5, Kanda-Surugadai Chiyoda-ku, Tokyo 101
August 19-24	1985 International Symposium on Lepton and Photon Interactions at High Energies	Kyoto, Japan	Research Institute for Fundamental Physics Kyoto University Oiwake-cho, Kita-shirakawa Sakyo-ku, Kyoto 606
August 19-30	The 23rd General Assembly of IASDPEI (International Association of Semismology and Physics of the Earth's Interior)	Tokyo, Japan	Intergroup Corporation Akasaka Yamakatsu Building 8-5-32, Akasaka Minato-ku, Tokyo 107
August 26-30	The 6th International Symposium on Polarization Phenomena in Nuclear Physics	Osaka, Japan	Professor M. Kondo Research Center of Nuclear Physics Osaka University Yamadaoka, Suita, Osaka 530
August (tentative)	Coastal Engineering Conference	Melbourne, Australia	The Conference Manager Australia The Institution of Engineers, Australia 11 National Circuit Barton, A.C.T. 2600
August (tentative)	International Association Hydraulic Resources Conference	Melbourne, Australia	The Conference Manager The Institution of Engineers, Australia 11 National Circuit Barton, A.C.T. 2600
August (tentative)	The 21st Congress for IAHR (International Association for Hydraulic Research)	Melbourne, Australia	Mr. Robin Vickery Institute of Engineers Australia 11 National Circuit Barton, A.C.T. 2600

1985 Continued

Date	Title	Site	For Information, contact
August (tentative)	The 8th IUPAC Conference on Physical Organic Chemistry	Tokyo, Japan	Professor M. Oki Department of Chemistry Chemistry Faculty of Science University of Tokyo 7-3-1, Hongo Bunkyo-ku, Tokyo 112
September 4-11	The 11th International Teletraffic Congress ITC-11	Kyoto, Japan	ITC-11 Committee Musashino Electrical Com- munication Laboratory 3-9-11, Midorimachi Musashino, Tokyo 180
September 6-10	1985 Annual Conference of the IIC (International Institute of Communications)	Tokyo, Japan	International Relations Department Japan Broadcasting Corporation 2-2-1, Jinnan Shibuya-ku, Tokyo 150
September 10-13	The 3rd International Cell Culture Congress	Sendai, Japan	Professor S. Yamane Research Institute for <i>Tuberculosis and Cancer</i> Tohoku University 4-1, Seiko-cho Sendai, Miyagi 980
September 21-25	World Congress III of Chemical Engineering	Tokyo, Japan	Secretariat, the Society of Chemical Engineers Kyoritsu Building 6-19, Kohinata 4-chome Bunkyo-ku, Tokyo 112
October 15-18	International Rubber Conference	Kyoto, Japan	The Society of Rubber Industry, Japan Tobu Building 1-5-26, Motoakasaka Minato-ku, Tokyo 107
October 19-22	The 5th International Symposium on Rats with Spontaneous Hypertension and Related Studies	Kyoto, Japan	Professor Yukio Iemori Shimane Medical University 89-1, Shioji-cho Izumo, Shimane 693

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March 16-21	The 10th International Congress of Prestressed Concrete	New Delhi, India	Mr. C. R. Alimchandani Stup Consultant, Ltd. 1004-5-7, Raheja Chambers 213 Nariman Point Bombay 420-021
May 11-17	Congress of the International Society of Haematology and the International Society of Blood Transfusions	Sydney, Australia	Dr. I. Cooper, President Haematology Society of Australia Cancer Institute 481 Little Lonsdale Street Melbourne, Victoria 3001
July (tentative)	International Institute of Welding Annual Assembly 1986	Tokyo, Japan	Japan Welding Society 10-11, Kanda-Sakumacho Chiyoda-ku, Tokyo 101
August 25-29	The 12th International Congress of the International Association of Sedimentologists	Canberra, Australia	Professor K.A.W. Crook Department of Geology Australian National University P.O. Box 4 Canberra, A.C.T. 2600
August 26-30	International Conference on Martensitic Transformations (ICOMAT-86) in Commemoration of JIM 50th Anniversary	Nara, Japan	ICOMAT-86 The Japan Institute of Metals (JIM) Aoba, Aramaki Sendai 980
August (tentative)	The 7th World Congress on Air Quality	Sydney, Australia	Mr. K. Sullivan Clean Air Society of Australia and New Zealand P.O. Box 191 Eastwood, N.S.W.
September 21-25	The World Congress of Chemical Engineering	Tokyo, Japan	The Society of Chemical Engineers, Japan Japan Kyoritsu Kaikan 4-6-19, Honhinata Bunkyo-ku, Tokyo 112
September (tentative)	The 8th International Congress of Psychosomatic Obstetrics and Gynecology	Melbourne, Australia	Dr. L. Dennerstein Department of Psychiatry University of Melbourne c/o Royal Melbourne Hospital Parkville, Melbourne 3052

1986 Continued

Date	Title	Site	For Information, contact
Undecided	International Microbiological Congress	Perth, Australia	Australian Academy of Science P.O. Box 783 Canberra, A.C.T. 2601

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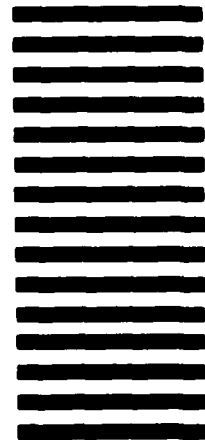
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